01 SOLID FUELS

Sources, winning, properties

14/02360 Analysis of deposits collected under staged conditions in a pulverized coal reactor for eight US coals

Stimpson, C. K. *et al. Applied Energy*, 2013, 110, 65–72.

Deposit samples for eight coals were collected on stainless steel probes in reducing and oxidizing regions of a 160 kW_{th}, down-fired, pulverized coal reactor. Firing conditions in the reactor and probe temperatures were controlled to simulate an industrial furnace operating on an advanced ultra-supercritical steam cycle, 500 °C in the near burner region and 750 °C in the oxidizing region. The samples were analysed using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) to determine particle sizes and elemental compositions. Deposited particles on the top or upstream side of the probes were larger and more irregular in shape. Particles that deposited on the bottom or downstream side of the probes were smaller and more spherical. The SEM–EDS analysis showed each particle consisted of a unique composition of elements. The sulfur concentrations measured in the deposits were averaged for the upstream and downstream side of each specimen and were not found to correlate with sulfur concentrations of their respective coals, but they were strongly correlated with the calcium and iron contents of their respective coals. The high-calcium, sub-bituminous and lignite coals produced high sulfur concentrations in the deposits, particularly in the downstream, oxidizing deposits. The high-iron, bituminous coals produced high sulfur concentrations primarily in upstream, reducing deposits. The relatively low-calcium and low-iron bituminous coals produced low sulfur concentrations in the deposits. Although high in iron, the Mahoning coal deposits contained low sulfur concentrations.

14/02361 FTIR and simultaneous TG/MS/FTIR study of Late Permian coals from Southern China

Wang, S. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 75–80.

Five coals selected from south China were studied by proximate analysis, ultimate analysis and Fourier transform infrared (FTIR) spectroscopy with curve-fitting analysis to obtain information on the chemical composition and chemical structure in the samples. The thermogravimetric behaviours of these samples and their evolution of gaseous compounds during pyrolysis were studied by thermogravimetry coupled with mass spectrometry and FTIR spectroscopy (TG/MS/FTIR). The results showed that the chemical structures of these samples are characterized by relatively higher amounts of aliphatic groups while the degree of aromatization/condensation is low. In addition, these samples (except MS-5) have good hydrocarbon-generating potential. The thermogravimetric experiments showed that these samples undergo intense thermal decomposition. The information on the evolution of gaseous compounds (i.e. H_2, H_2O, CO, CO_2 and CH_4) during pyrolysis under the conditions used in this work can be provided by TG/MS/FTIR method and their evolution are different.

14/02362 Numerical simulation of electromagnetic radiation caused by coal/rock deformation and failure

Wang, E.-Y. and Zhao, E.-L. *International Journal of Rock Mechanics and Mining Sciences*, 2013, 57, 57–63.

Based on the stress distribution characteristics and energy dissipation and release theories, a theoretical model of the electromagnetic radiation (EMR) in coal is established. The model is used in conjunction with rock failure process analysis software (RFPA) to numerically simulate the processes of coal/rock deformation and failure, the characteristics of the stress distribution and EMR in the processes, and the effects of the coal compressive strength and loading rate on the EMR. The results show that: (1) the EMR signals generated by coal samples under uniaxial compression increase with stress until the samples fail, and after that the EMR signals decrease rapidly. This is consistent with experimental results and belongs to group-shock type; (2) the EMR signals generated by rock samples under uniaxial compression reach their peaks at the time of main failure, and after that and in initial loading, the signals are weak. that is consistent with experimental results and belongs to main-shock type; (3) the greater the compressive strength of a coal sample is, more time delays its failure results in, and the higher the peak stress becomes; EMR signals generated in the breaking process of coal show an increasing trend. These results indicate that the theoretical model of EMR in coal can be used to study detailed EMR characteristics of coal in complex conditions.

14/02363 Safety technologies for the excavation of coal and gas outburst-prone coal seams in deep shafts

Wang, L. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 57, 24–33.

An analysis of the stress distribution characteristics of shaft working faces in deep underground coal mines was performed using theoretical analyses and field tests. The analysis of the outburst risk within the studied shaft demonstrated that a funnel-shaped pressure relief zone existed below the working face, and a zone of concentrated stress surrounding the shaft was a critical area for a potential outburst disaster. The authors divided the process of coal excavation within the shaft into four stages to manage and propose improved technical, drainage and protective measures as well as other requirements. When using the processes and requirements provided, the Haizi and Taoyuan coal mines, which are located in the Huaibei mining region and have depths of up to 1000 m, realized safe and rapid excavation through outburst-prone coal seams. It was determined that the technical systems developed in this paper could provide for safe coal excavation in deep shafts, which could be established as new regulations for rapid and safe coal extraction in outburst-prone coal seams.

14/02364 Synergistic effects on pyrolysis of binary and ternary coal blends studied by means of dynamic mechanical thermal analysis and Gieseler plastometer

Krzesińska, M. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 127–136.

Desirable values of technological indices of cokes produced from blends containing poor coking coals are expected due to mutual interactions between components during pyrolysis. The aim of this work was to study a synergistic effects postulated to occur during thermal decomposition of the binary (50 : 50) and the ternary blends of weakly-caking coals (from the Szczyglowice and Krupiński coal mines, Poland), blended with strongly caking coal (from the Zofiówka coal mine, Poland) of increasing content from 10 up to 100 wt% with step of 10 wt%. Pyrolysis of the blends was studied by means of the dynamic mechanical thermal analysis (DMTA) and the Gieseler plastometer. The results were related to the structure ordering degree of cokes performed from the blends mentioned above. Synergistic effects were detected in all blends, but strength of above was not the same. Divergences between temperature dependence of fluidity measured by the Gieseler plastometer and calculated one from the data of initial coals and their content in a blend under assumption of additivity, were higher for the binary blends in comparison with those of the ternary ones. The greatest synergistic effects were observed for the blends with the strongly caking coal content of 30–50 wt%, for which high ordering of structure was registered. For these blends the greatest dissipation of the oscillation energy supported by the DMTA apparatus was observed.

Preparation

14/02365 Developing coal pillar stability chart using logistic regression

Wattimena, R. K. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 58, 55–60.

Logistic regression was utilized to calculate the probability that a particular pillar of a given geometry (width-to-height ratio) and a known stress condition (strength-to-stress ratio) will be stable. The stable-failure boundary was also determined. The logistic regression was also used to calculate and draw isoprobability contours. These contours represent the probability of stability of coal pillars based on the probability function for each stability class and are a valuable design tool in quantifying the instability probability of coal pillars.

14/02366 Permeability evolution during progressive deformation of intact coal and implications for instability in underground coal seams

Wang, S. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 58, 34–45.

This study reports measurements of deformation, strength and permeability evolution during triaxial compression of initially intact coals. Permeability is continuously measured by the constant pressure differential method, together with axial and volumetric strains for both water (H_2O) and strongly adsorbing carbon dioxide (CO_2) gas. Strength and Young's modulus increase with increasing confining stress and permeability is hysteretic in the initial reversible deformation regime. As deviatoric stress and strain increase, permeability first decreases as pre-existing cleats close, and then increases as new vertical dilatant microcracks are generated. Post-peak strength the permeability suddenly increases by three or four orders-of-magnitude. During loading, the inflection point where permeability begins to increase occurs earlier than the turning point of volumetric strain, which may be explained by the competing processes of axial crack opening and closure of oblique and transverse cracks. The generation of these vertical microcracks does not enhance gas migration in the horizontal direction but will accelerate the rate of gas desorption and weaken the coal. Based on this mechanistic observation, the authors propose a process-based model for bursting in underground coal seams. Horizontal and vertical stresses redistribute ahead of the mining-face immediately after the excavation and influence pore pressure, permeability, and desorption rate. Due to this redistribution, the zone closest to the mining-face may experience tensile failure. Interior to this zone a region may develop with gas overpressures induced by desorption and this may contribute to the occurrence of coal and gas outbursts. Beyond this, an overstressed zone may initiate shear failure driven by gas pressures if the desorption rate outstrips the rate of drainage. The authors also discuss the implications of this on the instability of coal seams to CO_2 injection and the potential for induced fault slip.

Transport, storage

14/02367 Premixed methane-air deflagrations in a completely adiabatic pipe and the effect of the condition of the pipe wall

Jiang, B. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 782–791.

A completely adiabatic pipe that is similar to a coal-mine coal or rock roadway was simulated using the computational software AutoReaGas. A partially adiabatic pipe was established using an experimental steel pipe with heat-insulating material installed in the inner wall, and a non-adiabatic pipe was also established using the experimental steel pipe without the heat-insulating material. Premixed methane/air deflagrations were studied in the three types of pipe to reveal the influence of the condition of the pipe wall on gas explosions. The results showed that in the completely adiabatic pipe, the maximum explosion overpressure was dynamic and decreased and increased with increasing distance; however, the flame-propagation speed increased gradually. In the partially adiabatic pipe and the non-adiabatic pipe, the maximum explosion overpressure and flame-propagation speed increased initially and then gradually decreased with increasing distance. The majority of explosion overpressure and flame-propagation speed values at each gauge in the completely adiabatic pipe were larger than those of the partially adiabatic pipe. Both measurements at each gauge in the partially adiabatic pipe were much greater than those of the non-adiabatic pipe. The condition of the pipe wall has a large influence on the maximum explosion overpressure and the flame-propagation speed. In future explosion experiments, heat insulating materials should be installed in the inner wall of steel pipes to obtain data for application to the prevention and control of gas explosions in underground coal mines.

Economics, business, marketing, policy

14/02368 Carbon emission coefficient measurement of the coal-to-power energy chain in China

Yu, S. *et al. Applied Energy*, 2014, 114, 290–300.

Coal-fired electricity generation has become the largest source of carbon dioxide emissions in China. This study uses life-cycle assessment to assess the effect of carbon dioxide emissions and to calculate the coefficient of carbon dioxide emissions in coal-to-energy chains. Results show that the carbon dioxide emission coefficient of the coal-to-energy chain in China is $875\,\mathrm{g/kW\,h^{-1}}$, which is a relatively low level compared with that of other countries. Carbon dioxide is the main type of greenhouse gas emission and is the most abundant type of direct emission. China has to reduce electrical consumption in the coal-mining process to reduce carbon dioxide emissions in coal-to-energy chains. Moreover, China has to facilitate railway-line construction to improve the proportion of railway transportation to coal transportation.

14/02369 Case study of establishing a safe blasting criterion for the pit slopes of an open-pit coal mine

Choi, B.-H. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 57, 1–10.

The objective of this case study was to establish a safe blasting guideline that can secure the safety of pit slopes against blast-induced ground vibrations in Pasir coal mine, Indonesia. For the purpose, field measurements on the ground vibrations have been conducted to obtain peak particle velocity (PPV) data throughout the investigation periods. Based on the acquired data, a general prediction equation for the ground vibration level was derived. Also, the allowable level of ground vibration for the pit slopes was set to be $V_{\mathrm{allow}} = 130\,\mathrm{mm/s}$ of PPV based on the results of a numerical analysis. Then, using the prediction equation and the allowable level, the scaled distance inequality for the pit slopes was derived as $D_s \geq 5$ in order for the maximum charge weight per hole to be determined. In addition, a simple method of calculating the proper charge weight to meet the safe blasting criterion was illustrated using the concept of a blast scale function. An alternative initiation sequence, which can be used to control the fragmentation according to the direction of rock layers, was additionally suggested. Finally, several standard blasting patterns that can be used for the depth of hole of 3.3–8.5 m were presented for ease of field use. However, rock conditions encountered in everyday blasting will be different site by site. Hence, it is recommended that an optimum blasting pattern for a site of special interest be found through a series of test blasts based on the proposed standard patterns.

14/02370 Chinese coal supply and future production outlooks

Wang, J. *et al. Energy*, 2013, 60, 204–214.

China's energy supply is dominated by coal, making projections of future coal production in China important. Recent forecasts suggest that Chinese coal production may reach a peak in 2010–2039 but with widely differing peak production levels. The estimated ultimately recoverable resources (URR) influence these projections significantly, however, widely different URR-values were used due to poor understanding of the various Chinese coal classification schemes. To mitigate these shortcomings, a comprehensive investigation of this system and an analysis of the historical evaluation of resources and reporting issues are performed. A more plausible URR is derived, which indicates that many analysts underestimate volumes available for exploitation. Projections based on the updated URR using a modified curve-fitting model indicate that Chinese coal production could peak as early as 2024 at a maximum annual production of 4.1 Gt. By considering other potential constraints, it can be concluded that peak coal in China appears inevitable and immediate. This event can be expected to have significant impact on the Chinese economy, energy strategies and greenhouse gas emissions reduction strategies.

14/02371 Inflationary effect of coal price change on the Chinese economy

Chen, Z.-M. *Applied Energy*, 2014, 114, 301–309.

This study investigates the pass-through effect induced by coal price fluctuations on the Chinese economy 2007–2011 based on a non-competitive input–output model. Three scenarios with different domestic tariff regulation alternatives, actual regulation (AR), no regulation (NR) and strong regulation (SR), are simulated to reflect the effectiveness of different policies. At the sectoral scale, the coking sector has the largest price variation under all scenarios while agriculture sectors and services sectors are the least sensitive. Nation-level impacts are examined by the weighted price changes of commodities used for different purposes. With the government regulation in reality, about 5% of the gross domestic product (GDP) deflator and consumer price index changes as well as 25% of the producer price index change over the research period are attributed to coal price increase. Comparison shows the AR scenario brings more stable fluctuations but higher inflation than the NR scenario. The SR scenario confirms that authorities can remarkably relieve short-run inflation by controlling domestic electricity and heat tariffs. The induced inflationary expense sums up to between 0.03% and 0.97% of China's GDP, around three-quarters of which are burdened by investors and foreigners. The quantitative effect investigated in this study can serve as empirical evidence for policy makers regarding inflation control in China.

14/02372 Techno-economic analysis of the coal-to-olefins process in comparison with the oil-to-olefins process

Xiang, D. *et al. Applied Energy*, 2014, 113, 639–647.

Olefins are one of the most important oil derivatives widely used in industry. To reduce the dependence of olefins industry on oil, China is increasing the production of olefins from alternative energy resources, especially from coal. This study is concerned with the opportunities and obstacles of coal-to-olefins development, and focuses on making an overall techno-economic analysis of a coal-to-olefins plant with the capacity of 0.7 Mt/a olefins. Comparison is made with a 1.5 Mt/a oil-to-olefins plant based on three criteria including energy efficiency, capital investment and product cost. It was found that the coal-based olefins process show prominent advantage in product cost because of the low price of its feedstock. However, it suffers from the limitations of higher capital investment, lower energy efficiency and higher emissions. The effects of production scale, raw material price and carbon tax were varied for the two production routes, and thus the operational regions were found for the coal-to-olefins process to be competitive.

Derived solid fuels

14/02373 An investigation into the effect of fast heating on fluidity development and coke quality for blends of coal and biomass

Kokonya, S. *et al. Biomass and Bioenergy*, 2013, 56, 295–306.

The addition of biomass to coking coals can reduce operational costs and carbon emissions but also reduces fluidity development. The use of heating rates up to 20 °C min^{-1} in the softening stage of coal has been investigated using high-temperature small-amplitude oscillatory-shear rheometry to improve the fluid characteristics of binary blends of two coking coals with Scots pine. The effects of biomass concentration and particle size, biomass torrefaction, pellet mass and thermal pre-treatment of the blend on fluidity development and semicoke strength have also been studied. Fluidity increased with an increase in heating rate and an increase in the final temperature for fast heating. Relationships were found between the minimum complex viscosity of the blend, the heating rate and the concentration of biomass, which have been used to propose an equation to calculate the heating rate necessary to achieve optimum fluidity for a particular blend with biomass. The fluid characteristics of the blend were not affected to a great extent by the particle sizes of the biomass studied (<500 and >500 μm) or the torrefaction of the biomass (250 °C for 1 h in N_2), were increased by an increase in pellet mass, and were destroyed by blend pre-heating. The semicoke strength of the blend with a mass fraction of 10% Scots pine and fast heating (10 °C min^{-1}) proved to be higher than that of the coal alone with slow heating (3 °C min^{-1}) and resulted in a 3% reduction in non-renewable carbon emissions.

14/02374 Conversion of nitrogen compounds and tars obtained from pre-composted pig manure pyrolysis, over nickel loaded brown coal char

Li, L. and Takarada, T. *Biomass and Bioenergy*, 2013, 56, 456–463.

Fuel gas production and nitrogen transformation during pig manure pyrolysis from room temperature to 900 °C are investigated. The catalytic decomposition of the derived volatiles is also studied. Ammonia, HCN and N_2 were obtained as the main N-containing gases. Ammonia was mainly emitted below 700 °C, which corresponds to 24.8 wt% of the nitrogen in the manure. Hydrogen cyanide and N_2 gases obviously formed at temperatures above 700 °C, while the HCN concentration was as low as one-ninth that of NH_3 and one-fifth of the concentration of nitrogen even at 900 °C. Thermal cracking of the pyrolysis volatiles produced little NH_3, but noticeably increased HCN formation. When the prepared nickel-loaded brown coal char (LY-Ni) was added to the second part of the reactor (second stage) as a catalyst, most of the N-containing species in the volatiles converted into N_2 gas. It suggests that LY-Ni has high catalytic activity for the conversion of N-containing compounds. Significant quantities of light fuel gases (H_2, CO and CH_4) were also generated. Compared with sand, 5.8 times (H_2 and CO) the amount of gases was produced with the LY-Ni char at 650 °C. Decomposition of the manure volatiles depends on the catalyst temperature. Total product gases approximately doubled in yield when the catalyst temperature increased from 450 to 550 °C, and the volatiles conversion (based on carbon balance of the manure volatiles) increased from 72.4 to 92.0 wt%. At 600–700 °C, the volatiles conversions stabilized at high levels of 96.7–98.2 wt%.

14/02375 Conversion of sewage sludge to clean solid fuel using hydrothermal carbonization: hydrochar fuel characteristics and combustion behavior

He, C. *et al. Applied Energy*, 2013, 111, 257–266.

Conventional thermochemical treatment of sewage sludge (SS) is energy-intensive due to its high moisture content. To overcome this drawback, the hydrothermal carbonization (HTC) process was used to convert SS into clean solid fuel without prior drying. Different carbonization times were applied in order to produce hydrochars possessing better fuel properties. After the carbonization process, fuel characteristics and combustion behaviours of hydrochars were evaluated. Elemental analysis showed that 88% of carbon was recovered while 60% of nitrogen and sulfur was removed. Due to dehydration and decarboxylation reactions, hydrogen/carbon and oxygen/carbon atomic ratios reduced to 1.53 and 0.39, respectively. It was found that the fuel ratio increased to 0.18 by prolonging the carbonization process. Besides, longer carbonization time seemed to decrease oxygen containing functional groups while carbon aromaticity structure increased, thereby rendering hydrochars highly hydrophobic. The thermogravimetric analysis showed that the combustion decomposition was altered from a single stage for raw sludge to two stages for hydrochars. The combustion reaction was best fitted to the first order for both raw sludge and hydrochars. The combustion of hydrochars is expected to be easier and more stable than raw sludge because of lower activation energy and pre-exponential factor.

14/02376 Economic, environmental and social assessment of briquette fuel from agricultural residues in China – a study on flat die briquetting using corn stalk

Hu, J. *et al. Energy*, 2014, 64, 557–566.

Biomass can be relatively easily stored and transported compared with other types of renewable energy sources. Crop straw can be converted into densified solid biofuel via briquette fuel technology to expand its possible applications and enhance its utilization efficiency. However, the potential economic, environmental and social impacts of crop straw briquette fuel need to be assessed before its large-scale use. This paper provides an evaluation of these impacts for a fully-operating 2×10^4 t/a corn stalk briquette fuel plant in China. The results show that with a life time of 15 years, a purchase price of 150 RMB/t for corn stalk and the current sales price of 400 RMB/t for briquette fuel, the plant has a net present value of 9.6 million RMB (or US$1.5 million), an internal rate of return of 36% and a short investment payback period of 4.4 years. The life cycle greenhouse gas emissions are found to be 323 t CO_2,e/year or 1 kg CO_2,e/GJ, much lower than that of coal. Additionally, the process reduces pollution by decreasing the amount of corn stalk that is discarded or burnt directly in the field. In terms of social impacts, the use of corn stalk briquetting fuel plant is expected to play an important role in increasing local residents' income, improving rural ecological environments, alleviating energy shortages, guaranteeing energy security and promoting new rural reconstruction.

14/02377 Production of microporous biochars by single-step oxidation: effect of activation conditions on CO_2 capture

Plaza, M. G. *et al. Applied Energy*, 2014, 114, 551–562.

There is an urgent need to develop materials and processes that reduce the energy penalty associated with the CO_2 capture step. Biochars are appealing adsorbents for post-combustion CO_2 capture applications due to their low cost, stability in moisture conditions and microporous nature. A series of carbon adsorbents was prepared from almond shells and olive stones by single-step activation with air at 400–500 °C, and with lower O_2 concentration in the activating gas, 3–5%, at higher temperatures (500–650 °C). This process entails energy savings compared to conventional activation with carbon dioxide or steam. It has been found that the pore size distribution can be tailored by adequately selecting the activating conditions. Carbons obtained under lower oxygen partial pressures and higher temperatures present narrow microporosity, which is essential for the adsorption of CO_2 at low partial pressures. These appealing low-cost adsorbents have competitive CO_2 working capacities and high CO_2/N_2 equilibrium selectivity in conditions that can be considered representative for post-combustion CO_2 capture, thus showing potential for this application.

14/02378 Specimen size effects on the compressive strength and Weibull modulus of nuclear graphite of different coke particle size: IG-110 and NBG-18

Chi, S.-H. *Journal of Nuclear Materials*, 2013, 436, (1–3), 185–190.

The effects of specimen size on the compressive strength and Weibull modulus were investigated for nuclear graphite of different coke particle sizes: IG-110 and NBG-18 (average coke particle size for IG-110: 25 μm, NBG-18: 300 μm). Two types of cylindrical specimens, i.e. where the diameter-to-length ratio was 1 : 2 (ASTM C 695–91 type specimen, 1 : 2 specimen) or 1 : 1 (1 : 1 specimen), were prepared for six diameters (3, 4, 5, 10, 15 and 20 mm) and tested at room temperature (compressive strain rate: $2.08 \times 10^{-4}\,s^{-1}$). Anisotropy was considered during specimen preparation for NBG-18. The results showed that the effects of specimen size appeared negligible for the compressive strength, but grade-dependent for the Weibull modulus. In view of specimen miniaturization, deviations from the ASTM C 695–91 specimen size requirements require an investigation into the effects of size for the grade of graphite of interest, and the specimen size effects should be considered for Weibull modulus determination.

14/02379 Texture development in Fe-doped alumina ceramics via templated grain growth and their application to carbon nanotube growth

Çelik, Y. *et al. Journal of the European Ceramic Society*, 2013, 33, (6), 1093–1100.

Fe-doped alumina (Fe-Al_2O_3) materials with a controlled microstructure could be designed for some special uses such as a substrate for carbon nanotube growth. In this study, Fe-doped Al_2O_3 ceramics with varying degrees of texture were prepared via templated grain growth method and utilized for carbon nanotube synthesis by catalytic chemical vapour deposition in order to investigate how α-Al_2O_3 crystal orientation affects carbon nanotube growth in polycrystalline ceramics.

The degree of texture increased with the Fe content in the presence of liquid phase. Three kinds of carbon filaments (few-wall carbon nanotubes bundles, individual multi-wall nanotubes and carbon nanofibres) were observed over Fe-doped Al_2O_3 ceramics with varying degrees of texture depending on the surface roughness, crystallographic orientation and the size of the catalyst nanoparticles. While well-textured substrates with a rough surface led to a small amount of randomly oriented carbon nanotube bundles, perpendicularly oriented individual multi-wall nanotubes were obtained over relatively smooth single crystal α-Al_2O_3 platelet surfaces (basal planes) which remained in the matrix without growing.

02 LIQUID FUELS

Sources, properties, recovery

14/02380 A new reaction model for low temperature oxidation of heavy oil: experiments and numerical modeling

Khansari, Z. *et al. Energy*, 2014, 64, 419–428.

In situ combustion (ISC)-based enhanced heavy oil recovery is complex because there are numerous chemical reactions taking place simultaneously. The complexity arises due to the immense number of components reacting through many different reaction paths where the geology and oil saturation vary spatially within the reservoir. It is known that there are four major classes of reactions taking place within ISC: low-temperature oxidation (LTO), high-temperature oxidation (HTO), thermal cracking (TC) and aquathermolysis. Within the reservoir, during ISC, LTO and TC reactions play a major role by providing fuel for HTO. In many reaction schemes in the literature, the LTO interval is considered as a single reactive zone spanning a single temperature range. In this work, a new reaction scheme is proposed based on analysis of previously published thermogravimetric data where the LTO reaction temperature range is separated into four temperature sub-ranges each with its own dominant reaction products. The new reaction model was implemented in a numerical model that revealed that it was able to represent the four LTO temperature sub-ranges. In comparison, a numerical model using a previously published LTO reaction model with a single temperature range was not able to represent the behaviour of LTO.

14/02381 Bottom-up modeling of oil production: a review of approaches

Jakobsson, K. *et al. Energy Policy*, 2014, 64, 113–123.

Bottom-up models of oil production are continuously being used to guide investments and policymaking. Compared to simpler top-down models, bottom-up models have a number of advantages due to their modularity, flexibility and concreteness. The purposes of this paper is to identify the crucial modelling challenges, compare the different ways in which nine existing models handle them, assess the appropriateness of these models, and point to possibilities of further development. The conclusions are that the high level of detail in bottom-up models is of questionable value for predictive accuracy, but of great value for identifying areas of uncertainty and new research questions. There is a potential for improved qualitative insights through systematic sensitivity analysis. This potential is at present largely unrealized.

14/02382 On in situ hydrogen sulfide evolution and catalytic scavenging in steam-based oil sands recovery processes

Kapadia, P. R. *et al. Energy*, 2014, 64, 1035–1043.

In the steam-assisted gravity drainage (SAGD) process, high-temperature saturated-steam is injected into an oil sands reservoir to lower the viscosity of the bitumen hosted within the reservoir. Typical steam temperatures range from 200 to 260 °C. Under these conditions, the bitumen, in presence of steam–condensate, undergoes aquathermolysis yielding H_2S and CO_2. Current SAGD simulation models take into account complex spatial heterogeneity of geology and oil composition and the physics of heat transfer, multiphase flow, gas solubility effects, and viscosity variations with temperature; however, few have taken the chemistry of SAGD into account. Here, the authors have added aquathermolysis reactions to a simulation model to understand H_2S reactive zones in SAGD. Given the requirement to constrain sulfur emissions from thermal recovery processes, it is necessary to reduce H_2S production to surface. The results demonstrate that injecting small amount of SO_2, along with steam, initiates the Claus reaction in the reservoir which converts H_2S into liquid sulfur. Thus, sulfur emissions are reduced below that of the original operation without SO_2 co-injection. The ability to use *in situ* Claus reaction-based H_2S scavenging offers an elegant way to reduce sulfur emissions from thermal oil sands recovery processes.

14/02383 Solar-generated steam for oil recovery: reservoir simulation, economic analysis, and life cycle assessment

Sandler, J. *et al. Energy Conversion and Management*, 2014, 77, 721–732.

The viability of solar thermal steam generation for thermal enhanced oil recovery (TEOR) in heavy-oil sands was evaluated using data from the San Joaquin Valley in California, USA. The effectiveness of solar TEOR was quantified through reservoir simulation, economic analysis and life-cycle assessment. Reservoir simulations with continuous but variable rate steam injection were compared with a base-case Tulare Sand steamflood project. For equivalent average injection rates, comparable breakthrough times and recovery factors of 65% of the original oil in place were predicted, in agreement with simulations in the literature. Daily cyclic fluctuations in steam injection rate do not greatly impact recovery. Oil production rates do, however, show seasonal variation. Economic viability was established using historical prices and injection/production volumes from the Kern River oil field. For comparison, this model assumes that present-day steam generation technologies were implemented at TEOR start-up in 1980. All natural gas cogeneration and 100% solar fraction scenarios had the largest and nearly equal net present values of \$12.54 billion and \$12.55 billion, respectively. Solar fraction refers to the steam provided by solar steam generation. Given its large capital cost, the 100% solar case shows the greatest sensitivity to discount rate and no sensitivity to natural gas price. Because there are very few emissions associated with day-to-day operations from the solar thermal system, life-cycle emissions are significantly lower than conventional systems even when the embodied energy of the structure is considered. It was estimated that less than 1 g of CO_2/MJ of refined gasoline results from the TEOR stage of production if solar energy provides all steam. By this assessment, solar thermal or supplemental solar generation systems appear to be a preferred alternative to fully conventional systems using natural gas in areas with large solar insolation.

Transport, refining, quality, storage

14/02384 A feasibility study on the application of microwaves for online biofilm monitoring in the pipelines

Saber, N. *et al. International Journal of Pressure Vessels and Piping*, 2013, 111–112, 99–105.

This study investigates the potential of microwave technique for online monitoring and evaluation of biofilms in the pipelines. A microwave vector network analyser and an in-house built transmitting and receiving coaxial-line transducer were employed to transmit microwave signals in the pipe. The brass pipe specimen was tested by adhering different volumes of polymeric tape layers onto its internal surface simulating the biofilm build-up. By taking the pipe as a circular waveguide of microwave, the frequency domain measurements were conducted in the 45–47 GHz range with TM_{01} dominant wave mode. The permittivity of the biofilm-contained area has been expressed as a function of the resonance frequency after establishing the resonance condition in the waveguide. It was realized that the resonance frequencies experience systematic shifts with the growth of biofilm layer length and thickness. The effects of dielectric material properties and the volume of the added biofilm layer on the resonance frequency records were then explained using the cavity perturbation theory which confirmed the experimental findings. Measurement results indicated a high degree of sensitivity to the small amounts of introduced biofilm which proves the potential of the microwave technique for online biofilm monitoring in both closed-end and open-end terminal conditions.

14/02385 A study of spreading of crude oil in an ice channel

Bellino, P. W. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 558–561.

An oil spill on solid ice poses unique challenges to that of a spill on water or land. One challenge, which this study has elected to investigate, is the tendency of ice to crack and form channels. These channels are able to transport the oil away from the main mass of the spill making efficient clean-up difficult. Within the context of *in situ* burning, the oil channels may expedite the critical thickness of the oil spill being reached. A series of bench scale tests using a 100 cm long ice channel were conducted to study the effects of varying ice channel widths on the spread of an oil mixture, to mimic solid sea ice conditions that may be found in higher latitudes. Results suggest that spread rates of oil in ice channels approximately follows a viscous two-dimensional box model. The implication of these results on *in situ* burning of oil in icy conditions is discussed.

14/02386 Comparison of API 510 pressure vessels inspection planning with API 581 risk-based inspection planning approaches

Shishesaz, M. R. *et al. International Journal of Pressure Vessels and Piping*, 2013, 111–112, 202–208.

To ensure mechanical integrity, all pressure vessels shall be inspected at the intervals provided in inspection codes or based on a risk-based inspection (RBI) assessment. The RBI assessment may allow previously established inspection intervals to be extended. This paper describes the methodology, analysis and results of two RBI studies conducted on 293 pressure vessel components in two crude oil distillation units. Based on API RBI methodology in API 581 (2008), risk target concept was used for determining inspection dates. It was shown that when thinning is the major active damage, the RBI recommended intervals are as long as twice the API 510 intervals. This paper summarizes that, as a fundamental step in the risk calculation, RBI has a more defined methodology for evaluating equipment for multiple damage mechanisms and a more defined approach to specify the use of other inspection technologies beyond the traditional visual, ultrasonic, and radiography tests.

14/02387 Comparison of API650–2008 provisions with FEM analyses for seismic assessment of existing steel oil storage tanks

Hosseinzadeh, N. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 666–675.

API650–2008 is one of the prominent codes consisting of seismic specifications to design steel storage tanks for earthquakes resistance. In spite of the code's broad application, there are some failure modes such as slide bottom, elephant-foot buckling, sloshing and uplift needing more evaluation. In this paper, 161 existing tanks in an oil refinery complex have been classified into 24 groups and investigated using both API650–2008 rules and numerical finite element method (FEM) models. Failure modes and dynamic characteristics of studied models have been calculated by numerical FEM analysis and compared with code requirements. The results demonstrate that, in some cases, there are some imperfections in the code requirements that require further investigation.

14/02388 Effect of gasoline composition on oxidative desulfurization using a phosphotungstic acid/activated carbon catalyst with hydrogen peroxide

Xiao, J. *et al. Applied Energy*, 2014, 113, 78–85.

This work is concerned with the question of why oxidative desulfurization (ODS) catalyst that show good catalytic performance for ODS of model gasoline thiophenic compounds is not effective for real gasoline. For the first time, the effects of gasoline composition on ODS using a phosphotungstic acid/activated carbon (HPW/AC) catalyst with H_2O_2 were investigated. ODS of thiophene, one of the most difficult thiophenic compounds to be oxidized, was studied in a model fuel system, where a high thiophene conversion rate of 90% could be reached in 2 h at 90 °C. However, when applying the ODS to a real gasoline, the ODS conversion rate decreased to only 32%, suggesting a strong inhibiting effect of gasoline composition on ODS. The ODS studies in different model fuels suggested that the inhibiting effect can be ascribed to the competitive adsorption and oxidation with the presence of the alkenes and alkylated aromatic hydrocarbons in real gasoline. The active pi-electrons in alkenes and alkyl groups in alkylated aromatic hydrocarbons may react with polyoxoperoxo species or peroxo-metallate complexes formed by phosphotungstic acid–H_2O_2 interaction. Additionally, it was indicated that the ODS selectivity followed the order of benzothiophene > trimethylthiophene > dimethylthiophene ∼ methylthiophene > thiophene, suggesting the partial charge on the electron-rich sulfur atom may play a decisive role for its oxidation reactivity. To mitigate the inhibiting effect of gasoline composition on ODS, the following was proposed: (a) implementation of selective separation–oxidation processes; (b) choice of suitable selective oxidants; (c) optimization of selective ODS reaction temperature, etc. to improve ODS selectivity for real gasoline desulfurization applications.

14/02389 Effect of temper and hydrogen embrittlement on mechanical properties of 2,25Cr–1Mo steel grades – application to minimum pressurizing temperature (MPT) issues. Part II: vintage reactors & MPT determination

Pillot, S. *et al. International Journal of Pressure Vessels and Piping*, 2013, 110, 24–31.

Standard and Vanadium-alloyed 2,25Cr–1Mo steel grades (EN 10028–2 12CrMo9–10/ASTM A387 gr. 22 and 13CrMoV9–10/ASTM A542 tp. D) are commonly used for the fabrication of heavy pressure vessels for applications in petroleum refining plants. These reactors are made of heavy plates, forged shells, forged nozzles and fittings. They are subjected to thermal cycles (stop and go) and to severe service conditions (high temperatures and high hydrogen partial pressures). A primary concern for end-users is the definition of the minimum pressurizing temperature (MPT) of the equipment. This temperature is the lowest temperature at which the vessel can be repressurized after shutdown and insures no risk of brittle failure of the containment body. The MPT is defined by fracture mechanics and/or CVN approaches and calculations. This second part of the paper presents the methodology of MPT determination and the particular case of vintage reactors. MPT determination methodology is explained by using a virtual pressure vessel representative of vessels found in petroleum refineries. A special focus is also set on the evolution of embedded defects.

14/02390 Fast pyrolysis of *Miscanthus sinensis* in fluidized bed reactors: characteristics of product yields and biocrude oil quality

Bok, J. P. *et al. Energy*, 2013, 60, 44–52.

In this study, fast pyrolysis of *Miscanthus sinensis* was performed and the product yields and properties of the resulting biocrude oil were determined for varying reactor configurations and pyrolysis temperatures. Two types of reactors (rectangular and cylindrical fluidized beds) were adopted, and pyrolysis temperature was increased from 400 to 550 °C. Based on the results, it was found that the reaction temperature greatly influenced the product yield and the characteristics of biocrude oil. The highest yield of biocrude oil for the rectangular reactor was 48.9 wt%, produced at 500 °C, and the highest yield for the cylindrical reactor was 50.01 wt%, produced at 450 °C. Additionally, the biocrude oil yield in the rectangular reactor sharply decreased when reaction temperature was increased to 550 °C, while only a slight decrease was observed in the cylindrical reactor. From gas chromatography–mass spectrometry analysis, biocrude oil was found to contain various chemical components, such as non-aromatic ketones, furans, sugars, lignin-derived phenols, guaiacols and syringols. In particular, the sugar content of the biocrude oil produced in rectangular reactor (2.11–9.35 wt%) was generally lower than that produced in the cylindrical reactor (7.93–10.79 wt%).

14/02391 Optimal design of advanced drop-in hydrocarbon biofuel supply chain integrating with existing petroleum refineries under uncertainty

Tong, K. *et al. Biomass and Bioenergy*, 2014, 60, 108–120.

This paper addresses the optimal design of an advanced hydrocarbon biofuel supply chain integrated with existing petroleum refineries. Three major insertion points from the biofuel supply chain to the petroleum refineries are investigated and analysed, including bio-intermediates co-processed with crude oil, bio-intermediates co-processed with refinery intermediates, and finished biofuels blended with conventional petroleum products. A multiperiod, mixed-integer linear programming model is proposed that accounts for diverse conversion pathway, technology, and insertion point selections, biomass seasonality, geographical diversity, biomass degradation, demand distribution and government incentives. This model simultaneously optimizes the supply chain design, insertion point selection, and production planning. In addition, the conversion rate, operation cost associated with insertion points in petroleum refinery, as well as the biomass availability and product demand are modelled as fuzzy numbers to account for the data uncertainty. A fuzzy possibilistic programming approach is applied to this model, where possibility, necessity and credibility measures are adopted according to the decision makers' preference. This model is illustrated by the county level case study of Illinois. Compared to traditional biofuel supply chains, advanced hydrocarbon biofuel supply chain integrating with existing petroleum refinery infrastructure significantly reduces capital cost and total annualized cost.

14/02392 Safety assessment of potential supercritical solvents for Fischer–Tropsch synthesis

Hamad, N. A. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 528–533.

Fischer–Tropsch synthesis (FTS) is a primary pathway for gas-to-liquid (GTL) technology. In order to overcome commercial problems associated with reaction and transport phenomena, the use of supercritical solvents has been proposed to enhance conversion, catalyst stability and improve temperature control in fixed-bed reactors. One of the major challenges in designing the supercritical FTS reactor unit is selecting appropriate solvents of critical properties within the required reaction operating conditions. Numerous alternatives exist and should be screened based on relevant criteria. The main aim of this paper is to develop a screening methodology to identify an optimum supercritical solvent or a mixture of solvents that meet the aforementioned criteria while minimizing the cost and more importantly satisfying the safety constraints. A safety metric system was developed in order to compare the risk issues associated with using different solvents. In addition, an economic analysis of using the different solvents was performed. Finally, a case study was solved to illustrate the use of the proposed metrics and the selection of solvents based on safety and techno-economic criteria.

14/02393 Upgrading of oils derived from hydrothermal treatment of microalgae by catalytic cracking over H-ZSM-5: a comparative Py–GC–MS study

Torri, C. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 101, 28–34.

Hydrothermal treatment (HTT) of microalgae produces an organic liquid (HTT oil) with potentiality as feedstock in biofuel development. Through this process, an oil with oxygen content intermediate between pyrolysis oil from lignocellulosic biomass and fossil oil can be obtained even from lipid-poor microalgal species. However, the elevated content of nitrogen-containing organic compounds derived from algal proteins represents one of the main drawbacks. In this study, catalytic pyrolysis of HTT oil with H-ZSM-5 zeolite was investigated as an upgrading process, in order to reduce the nitrogen content and improve fuel quality. Oils obtained at various HTT experimental conditions from *Desmodesmus* sp. were mixed with H-ZSM-5 and pyrolysed at 600 °C within a Py–GC–MS system for the analysis of the evolved pyrolysis products. The results were compared with those resulting from catalytic pyrolysis of cellulose, *n*-hexatriacontane ($C_{36}H_{74}$) and pyrolysis oils from poplar (original and after hydrogenation). The relative comparison showed that hydrocarbon yields from pyrolysis of HTT oils over H-ZSM-5 were intermediate between those of hexatriacontane and cellulose. The high nitrogen content of the HTT oils did not show any marked effect on yields of hydrocarbons and nitrogen removal was remarkably high in all the investigated HTT oils. Although the data should be confirmed on larger scale, and recycling of catalyst has to be proven, obtained results indicate that it would be possible to introduce HTT oil from microalgae in existing refineries.

14/02394 Using MCFC for high efficiency CO_2 capture from natural gas combined cycles: comparison of internal and external reforming

Campanari, S. *et al. Applied Energy*, 2013, 112, 772–783.

In recent years, several research groups have proposed the combination of molten carbonate fuel cells (MCFCs) and gas turbine cycles for the application to CO_2 capture. One of the most promising configuration relies on the use of MCFCs as 'active CO_2 concentrator' in combined cycles (CCs): the fuel cell is placed downstream the gas turbine and ahead the heat recovery steam generator (HRSG), to concentrate the CO_2 from the gas turbine exhaust feeding the cathode, to the anode (where CO_2 is transferred together with oxygen) and generate electricity; while exhaust heat released by the cell effluents is recovered by the steam cycle. It has been shown that such plant configuration can capture 70–85% of CO_2 with small efficiency penalties compared to the combined cycle, and increasing by about 20% the overall power output (mainly given by the MCFC section); hence, this configuration could have relevant advantages with respect to competitive carbon capture technologies. This work presents a comprehensive discussion of the results of a modelling activity developed at Politecnico di Milano regarding the possible use of MCFCs for high efficiency CO_2 capture from combined cycles. The work discusses different types of MCFC–CC cycles, focusing on the comparison of two families of MCFC and corresponding power plants, which have been discussed only separately in the past. The MCFC can be fed with natural gas according to an internal reforming or external reforming process, according to the technological proposals of different MCFC manufacturers. Then, the anode exhaust stream of the MCFC, where is concentrated the majority of CO_2, is sent to a CO_2 purification section which can be based on (i) a cryogenic CO_2 separation section, or (ii) an oxy-combustion of residual fuel components, followed by cooling, condensation of water and separation of CO_2. In both cases, a high purity CO_2 stream is obtained and pumped to liquid form for storage. Detailed results are presented in terms of energy and mass balances of the different proposed cycles, evidencing pros and cons of the different layout and pointing out the role of relevant FC operating parameters (CO_2 utilization, operating current density and voltage) on the overall balances. Moreover, it is presented a comparison between the best proposed cycles and conventional NGCC–CCS systems.

Economics, business, marketing, policy

14/02395 A risk management approach to the economic and environmental strategic design of ethanol supply chains

Giarola, S. *et al. Biomass and Bioenergy*, 2013, 58, 31–51.

A general mixed integer linear programming modelling framework supporting strategic design and planning decisions for multi-period and multi-echelon ethanol supply chains is developed and implemented. Multiple biomass and technology options involving both first and second generation production are addressed for paving the way towards sustainable and feasible energy infrastructures. The ethanol supply chain is optimized according to a comprehensive mathematical framework where multiple decision criteria are simultaneously considered in an uncertain market scenario. In particular, the economic and environmental performances are both optimized also considering the decision-makers' risk mitigation preferences. Carbon cost emissions allowances trading scheme, crop management and technology learning issues are encompassed, too. A demonstrative case study is proposed involving the potential future Italian biomass-based ethanol production. Results show the effectiveness of the modelling framework as a decision making-tool to steer decisions and investments in the long term horizon among different ethanol fuel configurations.

14/02396 Asymmetric and nonlinear pass-through of crude oil prices to gasoline and natural gas prices

Atil, A. *et al. Energy Policy*, 2014, 65, 567–573.

This study uses the recently developed non-linear autoregressive distributed lags model to examine the pass-through of crude oil prices into gasoline and natural gas prices. This approach allows the simultaneous testing the short- and long-run non-linearities through positive and negative partial sum decompositions of the predetermined explanatory variables. It also offers the possibility to quantify the respective responses of gasoline and natural gas prices to positive and negative oil price shocks from the asymmetric dynamic multipliers. The obtained results indicate that oil prices affect gasoline prices and natural gas prices in an asymmetric and non-linear manner, but the price transmission mechanism is not the same. Important policy implications can be learned from the empirical findings.

14/02397 Energy profitability analysis for microalgal biocrude production

Ramos Tercero, E. A. *et al. Energy*, 2013, 60, 373–379.

This work presents the results of a thorough energy return on energy investment (EROEI) analysis for biocrude production from microalgae processes. The study investigated alternatives in order to maximize the energy recoveries of each process considered, which has been modelled and simulated by Aspen Plus. The estimates for feeds and recirculation of microalgae and nutrients, working conditions, systemization and equipment requirements were obtained using both literature and own experimental data. The pinch technology analysis was applied to optimize the process operating conditions. It was found that the process, which uses the combustion of biomass after biocrude extraction, is the most favourable one in energy terms. In particular, two cases of this type were addressed and compared to a base case where all energy requirements (heat and electrical) are provided from external sources: case 1, electricity is supplied externally whereas the biomass and part of the biocrude produced are burned to meet the requirements of thermal energy, and case 2, where the energy recovered from both biomass and part of biocrude are used to fulfil all heat and electricity duties. These cases were analysed also when the nitrogen needed for microalgae growth was obtained from wastewaters. Favourable EROEI figures could be calculated.

14/02398 Environmental and economic effects of high petroleum prices on transport sector

Solaymani, S. and Kari, F. *Energy*, 2013, 60, 435–441.

Using Malaysia as a case study in comparison with other studies that apply aggregate models, this study employs a multi-sector computable general equilibrium (CGE) model to derive the short-run and long-run effects of sustained increase in world petroleum prices on the transport sector. Since the transport sector is the main consumer of petroleum products, the study highlights the transmission channels through which the rising cost of petroleum products affects this sector in particular. The simulation results suggest that in the short-run, the effects of the shock are negative towards the economy and the transportation sector, but it will eventually encourage the reallocation of resources and, therefore, induces inequality in sectoral adjustments. However, in the long run, the shock will be beneficial for the transportation sector because it will contribute to an increase in domestic output and stimulate investment. In the whole of the economy and all transportation sectors, the shock will lead to an increase in the emissions of all air pollutants in the short run while it decreases them in the long run.

14/02399 Forecasting the limits to the availability and diversity of global conventional oil supply: validation

Hallock Jr., J. L. *et al. Energy*, 2014, 64, 130–153.

Oil and related products continue to be prime enablers of the maintenance and growth of nearly all of the world's economies. The dramatic increase in the price of oil through mid-2008, along with the coincident (and possibly resultant) global recession, highlight the continued vulnerability to future limitations in the supply of cheap oil. The very large differences between the various estimates of the original volume of extractable conventional oil present (extractable ultimate resource, EUR) have, at best, fostered uncertainty of the risk of future supply limitations among planners and policy makers, and at worse lulled the world into a false sense of security. In 2002 the authors modelled future oil production in 46 nation-units and the world by using a three-phase, Hubbert-based approach that produced trajectories dependent on settings for EUR, demand growth, percentage of oil resource extracted at decline, and maximum allowable rates of production growth. They analysed the sensitivity of the date of onset of decline for oil production to changes in each of these input parameters. In this study, the authors compare the past 11 years of empirical oil production data to their earlier forecast scenarios to evaluate which settings of EUR and other input parameters had created the most accurate projections. When combined with proper input settings, the model consistently generated trajectories for oil production that closely approximated the empirical data at both the national and the global level. In general, the lowest EUR scenarios were the most consistent with the empirical data at the global level and for most countries, while scenarios based on the mid and high EUR estimates overestimated production rates by wide margins globally. The global production of conventional oil began to decline in 2005, and has followed a path over the last 11 years very close to the scenarios assuming low estimates of EUR (1.9 Gbbl). Production in most nations is declining, with historical profiles generally consistent with Hubbert's premises. While new conventional oil discoveries and production starts are expected in the near term, the magnitudes necessary to increase the simulated production trajectories by even 1.0% per year over the next 10 years would represent a large departure from current trends. The now well-validated simulations are at significant variance from many recent 'predictions' of extensive future availability of conventional oil.

14/02400 Integration of techniques for early fault detection and diagnosis for improving process safety: application to a fluid catalytic cracking refinery process

Agudelo, C. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 660–665.

This paper considers the integration of techniques for early fault detection and diagnosis of operational faults in industrial processes, and provides an application example in a fluid catalytic cracking refinery process. The early fault detection and diagnosis allow the operators in an industrial process to take the best actions during the real state of the process, avoiding incipient faults to scale to critical situations where there is risk of human lives and economical lost.

14/02401 Persistence in crude oil spot and futures prices

Ozdemir, Z. A. *et al. Energy*, 2013, 59, 29–37.

This study investigates the degree of persistence in monthly Brent crude oil spot and futures prices (at 1, 2 and 3 months to maturity). The main finding from the full sample shows that Brent crude oil spot, 1, 2 and 3 months to maturity futures prices are characterized by a high degree of persistence without structural breaks. However, these prices are not highly persistent when structural breaks are taken into consideration. The analysis is repeated for four sub-periods delineated by the endogenously determined break points. The results obtained from the sub-period analysis indicate that oil price series are typically very persistent which is consistent with the efficient market hypothesis.

14/02402 Production costs of global conventional and unconventional petroleum

Aguilera, R. F. *Energy Policy*, 2014, 64, 134–140.

Concerns about the costs of developing oil and gas from conventional and unconventional formations have led many commentators to assume that increasing prices are in the offing and may be a limiting factor for economic growth. Historically, production costs have fluctuated as influenced by the cost-increasing effects of depletion versus the cost-reducing effects of technological progress. This paper aims to review several methods for assessing current and long-term costs. Despite the uncertainty of such estimation, evidence shows that production costs in the foreseeable future might not increase dramatically and actually could decrease as petroleum development methods improve and additional supplies come online. Recent examples include the commercially viable production of unconventional oil and gas resources that has kept energy prices contained.

14/02403 Recurrent arrival of oil to Galician coast: the final step of the *Prestige* deep oil spill

Bernabeu, A. M. *et al. Journal of Hazardous Materials*, 2013, 250–251, 82–90.

Yearly monitoring in one of the most affected coastal zones by the *Prestige* oil spill, namely Nemiña and O Rostro beaches (north-western Spain), has been carried out since 2004. Topographic data of beaches revealed seasonal altimetric changes up to 4 m that would prevent the on shore persistence of oil. However, surficial and subsurficial oil was detected in the intertidal area of both beaches in all campaigns. The hydrocarbon analysis confirmed that this oil corresponded to the *Prestige* oil, even 9 years after the accident. Tar balls were highly biodegraded suggesting that the oil was accumulated on the subtidal sediments for a long time and transported to the coast by the action of waves. The present work provides new evidence of the long-term persistence of deep oil spills from wrecks in marine areas where the hydrodynamic conditions play a twofold key role, in determining the exposed coastal area to recurrent contamination and in burying and resurfacing the oil in the intertidal zone.

14/02404 Structural crisis in the oil and gas industry

Mitchell, J. V. and Mitchell, B. *Energy Policy*, 2014, 64, 36–42.

The structure of the oil and gas industry is being disrupted by technical developments which increase supply and reduce demand, the reversal of growth in demand in transport in member countries of the Organization for Economic Co-operation and Development (OECD) and less dependence of the USA and Europe on Middle Eastern oil supplies. Upstream, expectations of scarcity are changing to expectations that, at current prices, national oil companies face increasing competition from public listed companies which use diverse advanced technologies to develop reserves in areas outside the control of national oil companies (NOC). The public listed companies also have the opportunity to bring specialized technology to match NOC needs. Downstream oil markets are dividing into the OECD markets where growth has been reversed and a non-OECD markets where it continues. This is a challenge for the major public listed companies whose downstream operations are concentrated in the OECD. They may respond by focusing on local advantages or by separating the downstream from their upstream businesses. The natural gas industry is being transformed by new discoveries, particularly in the USA, but regional markets remain separated by transport costs and pricing systems. The challenge will be to find prices which will grow both the supply and demand in each region.

14/02405 Systematic methodology for optimal enterprise network design between bio-refinery and petroleum refinery for the production of transportation fuels

Mahmoud, A. and Shuhaimi, M. *Energy*, 2013, 59, 224–232.

The production of transportation fuels from the conversion of biomass into gasoline and diesel in a bio-refinery is an attractive, clean, carbon neutral and sustainable process. The investment cost for the commercial application of a stand-alone bio-refinery may be reduced via integration with an existing petroleum refinery, whereby bio-refinery intermediates can be upgraded using the existing petroleum refinery infrastructure. In this work, two options of operational scenarios are studied and compared. The first option is to consider the bio-refinery and an existing petroleum refinery as stand-alone plants. The second option is to integrate bio-refinery network into an existing petroleum refinery and view it as an enterprise plant. The enterprise plant is represented in a superstructure, which is formulated as a mixed integer non-linear programming (MINLP) model. The MINLP model involves logic constraints to allow the conditional designing of the optimal enterprise plant network. The model application is demonstrated on representative case studies. The model results shows that the optimal enterprise plant network design achieved 2.82% ($21.5 MM/year) higher profit compared to the combined profits of the stand-alone plants. As a result, the payback time for a new bio-refinery investment is reduced from 6.9 to 4.7 years.

14/02406 The demand for road diesel in Canada

Barla, P. *et al. Energy Economics*, 2014, 43, 316–322.

This study estimates the demand for road diesel in Canada using aggregate annual data for the period 1986–2008. Using a partial adjustment model (PAM), short- and long-run price elasticities of -0.43 and -0.8, respectively, were found. However, using cointegration techniques, price elasticities were obtained that were 30–50% lower. The short-run elasticity with respect to gross domestic product per capita was evaluated at 0.5 with the PAM and 1.55 with cointegration. In the long run, both estimation techniques indicated an income elasticity of around 0.9. The results underline the importance of controlling the expansion of the primary sector which has been characterizing the Canadian economy in the 2000s.

14/02407 The impact of global oil price shocks on the Lebanese stock market

Dagher, L. and El Hariri, S. *Energy*, 2013, 63, 366–374.

This study investigates the dynamic linkages between oil prices and stock markets, also known as the oil price–stock price nexus. Within the framework of a vector autoregression (VAR), the authors examine dynamic interactions between daily Brent spot prices and several Lebanese stock prices. As expected, evidence was found of oil prices Granger causing stock prices, but no evidence of the opposite relationship. To better understand how shocks in the oil market are transmitted to the stock market, the orthogonalized impulse response function is examined. The behaviour of all stocks examined is very similar; they all respond positively to a shock in crude oil prices on the same day and the day after the shock, with the impact of the shock disappearing thereafter. As for the variance decomposition analysis, it shows that the forecast errors of the stocks are largely attributable to their own innovations and the percentages do not change much with time. Only around 1% is attributable to oil shocks, increasing to around 3% after a few days and remaining at that level. Thus, the main conclusion is that the estimated level of the impact of an oil price shock on the Lebanese stock market is positive but marginal.

14/02408 Un-burnable oil: an examination of oil resource utilisation in a decarbonised energy system

McGlade, C. and Ekins, P. *Energy Policy*, 2014, 64, 102–112.

This paper examines the volumes of oil that can and cannot be used up to 2035 during the transition to a low-carbon global energy system using the global energy systems model, TIAM-UCL and the ‘Bottom up Economic and Geological Oil field production model’ (BUEGO). Globally, in a scenario allowing the widespread adoption of carbon capture and storage (CCS), nearly 500 billion barrels of existing proven plus probable oil reserves must remain unused by 2035. In a scenario where CCS is unavailable this increases to around 600 billion barrels. Besides reserves, Arctic oil and light tight oil play only minor roles in a scenario with CCS and essentially no role when CCS is not available. On a global scale, 40% of those resources yet to be found in deep-water regions must remain undeveloped, rising to 55% if CCS cannot be deployed. The widespread development of unconventional oil resources is also shown to be incompatible with a decarbonized energy system even with a total and rapid decarbonization of energetic inputs. The work thus demonstrates the extent to which current energy policies encouraging the unabated exploration for, and exploitation of, all oil resources are incommensurate with the achievement of a low-carbon energy system.

14/02409 Well economics across ten tiers in low and high Btu (British thermal unit) areas, Barnett Shale, Texas

Gülen, G. *et al. Energy*, 2013, 60, 302–315.

This study evaluates the economics of drilling new wells in the Barnett Shale, Fort Worth Basin, Texas, USA. The analysis is the most granular public study to date because it is based on 10 productivity tiers and it treats low and high British thermal unit (Btu) segments of the play differently. The study is unique in its use of transient linear drainage production profiles that match the physics of the system and fit the production history in the Barnett very well. Average low Btu wells in the top two tiers are viable at $4/MMBtu, whereas average high Btu wells in the same tiers are economic at $2/MMBtu. Dry gas wells are the most sensitive to fluctuations in the price of natural gas whereas high Btu wells are also sensitive to the prices of oil and natural gas liquids. There is a distribution of productivity within each tier, with better wells requiring a much lower price to be viable than the average well. The granular subdivision of productivity, low versus high Btu, and intra-tier quality variation help to explain historical drilling patterns and also allow us to predict future development patterns in the field accurately as demonstrated for 2011 and 2012 in an earlier study.

Derived liquid fuels

14/02410 Converting of oil shale and biomass into liquid hydrocarbons via pyrolysis

Kiliç, M. *et al. Energy Conversion and Management*, 2014, 78, 461–467.

In this study, the co-pyrolytic behaviours of oil shale and *Euphorbia rigida* were investigated at different temperatures in a fixed bed reactor at 450, 500, and 550 °C with a heating rate of 10 °C/min in the presence of a nitrogen atmosphere. The obtained solid product (char) and liquid product (tar) were analysed by using different types of characterization techniques. Experimental results showed that co-pyrolysis of oil shale and biomass could be an environmental friendly way for the transformation of these precursors into valuable products such as chemicals or fuels.

14/02411 Hydrotreating of low temperature coal tar to produce clean liquid fuels

Li, D. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 245–252.

Clean liquid oil was obtained from low temperature coal tar (LCT) via hydrotreating in trickle-bed reactor (TBR) system filled with commercial catalysts. The effects of hydrogen pressure (10–16 MPa), reactor temperature (350–410 °C) and liquid hourly space velocity (LHSV) (0.25–1 h^{-1}) on hydrotreating performance were investigated while hydrogen to oil volume ratio was maintained constant at 1600 L$_N$/L in all cases. The degree of sulfur removal was greater than nitrogen removal with increasing temperature, pressure and contact time over the commercial catalyst. The TBR system was capable of removing nitrogen and sulfur from 1.14 and 0.34 wt % in the feed to 63 and 8 μg g^{-1}, respectively in the products. Gasoline (<180 °C) and diesel (180–360 °C) fraction were separated from the oil products and analysed. The gasoline fraction produced from LCT by hydrotreating comply with gasoline specifications for distillation range, sulfur content, induction period and gum presence. But it did not meet the specifications for research octane number specifications. Diesel fractions produced from LCT meet all quality tests as fuels that could be directly used as motor fuels without upgrading. The results indicated that the raw LCT could be considerably upgraded through catalytic hydrotreating and that high-quality fuels were obtained.

14/02412 Methanol production from steel-work off-gases and biomass based synthesis gas

Lundgren, J. *et al. Applied Energy*, 2013, 112, 431–439.

Off-gases generated during steelmaking are to a large extent used as fuels in process units within the plant. The surplus gases are commonly supplied to a plant for combined heat and power production. The main objective of this study has been to techno-economically investigate the feasibility of an innovative way of producing methanol from these off-gases, thereby upgrading the economic value of the gases. Cases analysed have included both off-gases only and mixes with synthesis gas, based on 300 MW$_{th}$ of biomass. The SSAB steel plant in the town of Luleå, Sweden has been used as a basis. The studied biomass gasification technology is based on a fluidized-bed gasification technology, where the production capacity is determined from case to case coupled to the heat production required to satisfy the local district heating demand. Critical factors are the integration of the gases with availability to the synthesis unit, to balance the steam system of the biorefinery and to meet the district heat demand of Luleå. The annual production potential of methanol, the overall energy efficiency, the methanol production cost and the environmental effect have been assessed for each case. Depending on case, in the range of 102,000–287,000 ton of methanol can be produced per year at production costs in the range of €0.80–1.1/litre petrol equivalent at assumed conditions. The overall energy efficiency of the plant increases in all the cases, up to nearly 14%-units on an annual average, due to a more effective utilization of the off-gases. The main conclusion is that integrating methanol production in a steel plant can be made economically feasible and may result in environmental benefits as well as energy efficiency improvements.

14/02413 Production of liquid alkanes by controlling reactivity of sorbitol hydrogenation with a Ni/HZSM-5 catalyst in water

Zhang, Q. *et al. Energy Conversion and Management*, 2014, 77, 262–268.

Liquid fuels derived from renewable biomass are of great importance on the potential substitution for diminishing fossil fuels. The conversion of sorbitol (a product of biomass-derived glucose hydrogenation) into liquid alkanes such as pentane and hexane over the Ni/HZSM-5 catalysts with or without MCM-41 addition was investigated in the presence of hydrogen in water medium. The production distribution of sorbitol hydrogenation can be controlled by adjusting the acidity of the catalyst. The scission of C–C bond in the sorbitol molecule into light C_1–C_4 alkanes was mainly carried out over Ni/HZSM-5 containing strong Brønsted acid sites, while C–O bond scission into heavier alkanes was dominated over the catalysts added by MCM-41 containing weak Lewis acid sites. The sorbitol conversion and total liquid alkanes selectivity were found to be 67.1% and 98.7% over 2%Ni/HZSM-5 modified by 40 wt% of MCM-41, whereas the corresponding value was 40% and 35.6% over 2%Ni/HZSM-5 in the absence of MCM-41. The effect of MCM-41 on the structure, acidity, and reducibility of Ni/HZSM-5 was investigated by using X-ray diffraction, pyrolysis infrared spectrometry, infrared spectrometry and H_2-temperature-programmed reduction. Meanwhile, the resistance of carbon deposition over the catalyst modified by MCM-41 was studied by using a thermogravimetric–differential scanning calorimetry technique. MCM-41 was found to have a positive interaction with HZSM-5 on the modulation of its structure properties and acidity, accompanying by the improvement on the reducibility of the catalyst. In addition, MCM-41 can distinctly decrease carbon deposition on the catalyst surface. These roles can favour the selective hydrodeoxygenation of C–O bond in the sorbitol molecule to generate liquid alkanes.

14/02414 The conversion of biomass into liquid hydrocarbon fuel by two step pyrolysis using cement as catalyst

Hussain, Z. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 101, 90–95.

Water hyacinth was used as biomass and converted into fuel oil and gas using catalytic pyrolysis. Ordinary cement was used as clinker catalyst for the pyrolysis of biomass. The oil was obtained by two step catalytic pyrolysis. The first reaction was found to give maximum product at 400 °C in 60 min. The amount of catalyst was used 30% of the weight of the biomass. The change in nature of product with change in concentration of the catalyst was investigated in terms of the increase in density of the pyrolysate. The second pyrolysis reaction was carried out under the same conditions. Both reactions were carried out in batch type static reactor. The process was found to give 7% oil and 29% fuel gases in addition to 14% water and 50% char. This product was qualitatively analysed using gas chromatography-mass spectrometry. The liquid oily product of the two-step catalytic pyrolysis was quantitatively analysed by gas chromatography equipped with a flame ionization detector and found it to be rich in hydrocarbons. In addition to hydrocarbons this oil was found to contain various quantities of the carboxylic acids, esters, alcohols, benzene-based aromatics and furan-based cyclic compounds.

14/02415 The intermediate pyrolysis of de-inking sludge to produce a sustainable liquid fuel

Ouadi, M. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 102, 24–32.

De-inking sludge is a waste product generated from secondary fibre paper mills who manufacture recycled paper into new paper sheets; it refers directly to the solid residues which evolve during the de-inking stage of the paper pulping process. The current practice for the disposal of this waste is either by land-spreading, land-filling or incineration, all of which are unsustainable. This work has explored the intermediate pyrolysis of pre-conditioned de-inking sludge pellets in a recently patented 20 kg/h intermediate pyrolysis reactor (the Pyroformer). The reactor is essentially two co-axial screws which are configured in such a way as to circulate solids within the reactor and thus facilitate in the cracking of tars. The potential application of using the volatile organic vapours and permanent gases evolved would be to generate both combined heat and power (CHP) located at paper-making sites. The results show that de-inking sludge could be successfully pyrolysed and the organic vapours produced were composed of a mixture of aromatic hydrocarbons, phenolic compounds and some fatty acid methyl esters as detected by liquid gas chromatography–mass spectroscopy. The calorific value of the oil after condensing was between 36 and 37 MJ/kg and the liquid fuel properties were also determined, permanent gases were detected by a gas chromatography–thermal conductivity detector and were composed of approximately 24% CO, 6% CH_4 and 70% CO_2 (v/v%). The solid residue from pyrolysis also contained a small residual calorific value, and was largely composed of mainly calcium-based inert metal oxides. The application of applying intermediate pyrolysis to de-inking sludge for both CHP production and waste reduction is in principle a feasible technology which could be applied at secondary fibre paper mills.

14/02416 Transportation fuels from co-processing of waste vegetable oil and gas oil mixtures

Rana, B. S. *et al. Biomass and Bioenergy*, 2013, 56, 43–52.

Hydroprocessing catalysts, sulfided Ni–W (on mesoporous silica–alumina) and Ni–Mo (on mesoporous γ-alumina), under typical hydroprocessing conditions, can very effectively produce liquid fuel from mixtures of waste vegetable oil and refinery gas oil. The acidity of the catalyst controls the relative amount of diesel range (straight chain) alkanes and cracked lighter products. The yield of diesel range (250–380 °C) product varied between 60 and 90%, while kerosene (jet) range product varied between 10 and 35% depending on the reaction conditions and type of catalyst used. The hydrodeoxygenation pathway for oxygen removal from triglyceride seems to be favoured over the Ni–Mo catalyst, while decarboxylation + decarbonylation pathway is favoured over the Ni–W catalyst and the respective pathways becomes more dominant with increasing vegetable oil content in the feed. Vegetable oil conversion does not adversely influence hydrodesulfurization of gas oil indicating viability of co-processing. The activation energy for overall S-removal is much lower than that for overall O-removal. Density and acidity of the products meet the required specification and cetane number is better than that for pure diesel.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

14/02417 Effect of progressive Co loading on commercial Co–Mo/Al_2O_3 catalyst for natural gas decomposition to CO_x-free hydrogen production and carbon nanotubes

Awadallah, A. E. *et al. Energy Conversion and Management*, 2014, 77, 143–151.

Successive cobalt increments from 3.1% up to 40.0% in a commercial hydrotreating catalyst containing originally 3.1%Co and 10.5%Mo on γ-Al_2O_3 was investigated at a reaction temperature of 700 °C and atmospheric pressure for the catalytic decomposition of natural gas to CO/CO_2-free hydrogen and carbon nanomaterials. The fresh and used catalysts were characterized by X-ray diffraction (XRD), Brunauer–Emmett–Teller, transmission electron microscopy (TEM), and thermo-gravimetric and differential thermal analysis analysis. The catalytic performance data showed that the increase of cobalt concentration improved the catalytic dissociation activity and longevity toward hydrogen production. All surface properties declined with successive addition of cobalt in the catalysts. XRD results showed that the crystallinity was remarkably enhanced and Co_3O_4 phases predominate upon addition of the cobalt precursor. The catalytic activity was found to be primarily dependent on the extent and degree of isolation of Co_3O_4 phases on the catalyst surface which reflects that the current reaction is a metal catalysed one. The influence of metal content on the total carbon yield and the degree of graphitization of the resulting carbon nanotubes was investigated by thermogravimetric analysis, XRD, Raman spectroscopy and TEM analysis.

14/02418 Experimental validation of GASDECOM for high heating value processed gas mixtures (58 MJ/m^3) by specialized shock tube

Botros, K. K. *et al. International Journal of Pressure Vessels and Piping*, 2013, 107, 20–26.

One of the fundamental requirements of the design of pipelines is the control of propagating ductile fracture, in which the Battelle two-curve method still forms the basis of the analytical framework used throughout the industry. The GASDECOM (gas decompression) tool is typically used for calculating decompression wave speed, which is one of these two curves. It uses the Benedict–Webb–Rubin–Starling (BWRS) equation of state to idealize the decompression process as isentropic and one-dimensional. While this equation of state was developed and validated against a quite restricted range of gas compositions, GASDECOM continues to perform relatively well for compositions slightly outside the original range of BWRS. The present research was focused on examining the performance of GASDECOM for mixture compositions up to a high (gross) heating value (HHV) of 58 MJ/m^3. Four tests were conducted using a specialized high pressure shock tube (42 m long, internal diameter = 38.1 mm) to experimentally determine the decompression wave speeds and compare them to the predictions by GASDECOM. Two tests were conducted on a gas mixture of HHV = 52 MJ/m^3 and the other two on even richer gas mixture of HHV = 58 MJ/m^3, all were from nominal initial pressures of 15 MPa and initial temperatures of 40 °C. The results from these tests show that decompression wave speeds are consistent with predictions of GASDECOM for gases of HHV typical of the previously validated range of BWRS. Predictions of the saturation pressure represented by the plateau pressure in the decompression wave speed curve were also in good agreement with measurements despite the fact that they occurred close to the critical point of the respective mixture compositions.

14/02419 Exploring the production of natural gas through the lenses of the ACEGES model

Voudouris, V. *et al. Energy Policy*, 2014, 64, 124–133.

Due to the increasing importance of natural gas for modern economic activity, and gas's non-renewable nature, it is extremely important to try to estimate possible trajectories of future natural gas production while considering uncertainties in resource estimates, demand growth, production growth and other factors that might limit production. In this study, the authors develop future scenarios for natural gas supply using the ACEGES computational laboratory. Conditionally on the currently estimated ultimate recoverable resources, the 'collective view' and 'golden age' scenarios suggest that the supply of natural gas is likely to meet the increasing demand for natural gas until at least 2035. The 'golden age' scenario suggests significant 'jumps' of natural gas production – important for testing the resilience of long-term strategies.

14/02420 Radiation energy devaluation in diffusion combusting flows of natural gas

Makhanlall, D. *et al. Energy*, 2013, 61, 657–663.

Computational fluid dynamics (CFD) is used to evaluate the thermodynamic second-law effects of thermal radiation in turbulent diffusion natural gas flames. Radiative heat transfer processes in gas and at solid walls are identified as important causes of energy devaluation in the combusting flows. The thermodynamic role of thermal radiation cannot be neglected when compared to that of heat conduction and convection, mass diffusion, chemical reactions and viscous dissipation. An energy devaluation number is also defined, with which the optimum fuel–air equivalence for combusting flows can be determined. The optimum fuel–air equivalence ratio for a natural gas flame is determined to be 0.7. The CFD model is validated against experimental measurements.

Transport, storage

14/02421 Comprehensive analysis of pipeline transportation systems for CO_2 sequestration. Thermodynamics and safety problems

Witkowski, A. *et al. Energy Conversion and Management*, 2013, 76, 665–673.

The aim of this paper is to analyse CO_2 compression and transportation processes with safety issues for post-combustion CO_2 capture applications for basic technological concepts of a 900 MW pulverized coal-fired power plant. Four various types of compressors including a conventional multistage centrifugal compressor, an integrally geared centrifugal compressor, a supersonic shock wave compressor, and pump machines were used. This study emphasizes that total compression power is a strong function of the thermodynamic process and is not only determined by the compressor efficiency. The compressor increases the CO_2 pressure from normal pressure to critical pressure and the boosting pump continues to increase the pressure to the required pressure for the pipeline inlet. Another problem analysed in this study is the transport of CO_2 by pipeline from the compressor outlet site to the disposal site under heat transfer conditions. Simulations were made to determine maximum safe pipeline distance to subsequent booster stations depending on inlet pressure, environmental temperature, the thermal insulation thickness and the ground level heat transfer conditions. From the point of view of environmental protection, the most important problem is to identify the hazards which indirectly affect CO_2 transportation in a strict and reliable manner. This identification is essential for effective hazard management. A failure of pipelines is usually caused by corrosion, material defects, ground movement or third-party interference. After the rupture of the pipeline transporting liquid CO_2, a large pressure drop will occur. The pressure will continue to fall until the liquid becomes a mixture of saturated vapour/liquid. In the vicinity of the rupture, liquid CO_2 will escape and immediately vaporize and expand. In the paper the discharge and atmospheric dispersion of CO_2 are discussed.

14/02422 Development and assessment of a distribution network of hydro-methane, methanol, oxygen and carbon dioxide in Paraguay

Rivarolo, M. *et al. Energy Conversion and Management*, 2014, 77, 680–689.

This paper summarizes key results of the analysis of different transport modes of hydro-methane, methanol, carbon dioxide and oxygen in Paraguay, Brazil and Argentina. Hydro-methane is produced in Paraguay and can be used to fuel natural gas vehicles, substituting gasoline and diesel which are at the moment imported. Methanol, also produced in Paraguay, is delivered to Brazil, which is one of the countries with the highest demand in the region. Oxygen is sold to Argentina for medical and industrial uses. Carbon dioxide is delivered throughout Paraguay. The aim of this study is to determine the best transportation technology from an economic and strategic point of view, minimizing costs associated to product distribution. Several scenarios are investigated. Each scenario is associated with different delivery modes. A model is developed to estimate both capital and variable costs for different transportation technologies (pipeline, trucks, ships) in order to choose the lowest-cost delivery mode for each product, depending on distances and flow rates. Four different analyses are performed for each scenario, varying the number of vehicles which must be fuelled by hydro-methane and considering its influence on the results. The methodology presented here has a general value, thus it can be easily employed for the economic analysis of different fuels and distribution networks, also placed in different scenarios.

14/02423 Gas transport networks: entry–exit tariffs via least squares methodology

Bermúdez, A. *et al. Energy Policy*, 2013, 63, 252–260.

Following some of the directives and regulations in the third European Union (EU) energy package, many of the member states are reconsidering their methodologies to derive the tariffs charged for access and usage of their gas transport systems. Among these methodologies, the use of entry–exit tariffs computed via least squares has received the most attention over the past few years and there is a wide consensus towards the application of this approach. The main contribution of this paper is to raise awareness on the fact that, even after a given methodology has been chosen, there are still important details to be fixed before the final tariffs are computed. Within the context of the least squares methodology, the authors argue that although many of these details may seem minor, they can have a big impact on the final outcome. The paper also presents proposals on how these details can be handled while still pursuing the goals set by the EU; goals such as being transparent, cost-reflective and non-discriminatory. Finally, the paper concludes with an illustration of the discussed proposals, applying them to the Spanish gas transport network.

14/02424 Pipeline politics – a study of India's proposed cross border gas projects

Nathan, H. S. K. *et al. Energy Policy*, 2013, 62, 145–156.

India's energy situation is characterized by increasing energy demand, high fossil fuel dependency, large import shares and a significant portion of the population deprived of modern energy services. At this juncture, natural gas, being the cleanest fossil fuel with high efficiency and cost-effectiveness, is expected to play an important role. India, with only 0.6% of proven world reserves, is not endowed with adequate natural gas domestically. Nevertheless, there are gas reserves in neighbouring regions which gives rise to the prospects of three cross-border gas pipeline projects, namely Iran–Pakistan–India, Turkmenistan–Afghanistan–Pakistan–India and Burma–Bangladesh–India. This study is a political analysis of these pipeline projects. First, it provides justification on use of natural gas and promotion of cross-border energy trade. Then it examines these three pipeline projects and analyses the security concerns, role of different actors, their positions, shifting goals and strategies. The study develops scenarios on the basis of changing circumstances and discusses some of the pertinent issues such as technology options for underground/underwater pipelines and role of private players. It also explores impact of India's broader foreign relations and role of the South Asian Association for Regional Cooperation on the future of pipelines and proposes energy induced mutually assured protection as a concept for regional security.

14/02425 Prediction of crack propagation and arrest in X100 natural gas transmission pipelines with the strain rate dependent damage model (SRDD). Part 1: a novel specimen for the measurement of high strain rate fracture properties and validation of the SRDD model parameters

Oikonomidis, F. *et al. International Journal of Pressure Vessels and Piping*, 2013, 105–106, 60–68.

A novel specimen for the measurement of strain rate and triaxiality dependent fracture properties of metals is described. The specimen is used in a conventional tensile split Hopkinson pressure bar test. The specimen is a flat 10 mm wide and 1 mm thick notched bar. Notch lengths between 2 and 8 mm were used. Several tests were performed on specimens cut from an X100 pipe at room temperature and strain rates up to $2000\,s^{-1}$. Finite element modelling of the stress–strain fields in the specimen immediately prior to crack propagation across the ligament was used to extract the flow properties, the damage initiation strain and the crack propagation energy as functions of stress triaxiality and strain rate. This data is used for tuning the strain rate dependent damage model (SRDD). The SRDD model was validated against the experiments and a good agreement was observed. In part 2 of this paper the tuned SRDD model is used for the simulation of an axial crack propagation and arrest in pressurized natural gas pipelines. Very good agreement with the burst tests is observed, thus validating the utility of the proposed specimen design and of the SRDD model.

14/02426 Stress intensity factor of semi-elliptical surface crack in a cylinder with hoop wrapped composite layer

Chen, J. and Pan, H. *International Journal of Pressure Vessels and Piping*, 2013, 110, 77–81.

In this paper the fracture behaviour of the compressed natural gas (CNG) cylinder with hoop wrapped composite layer is investigated for the axial crack at the inner surface. By the aid of the three-dimensional finite element method, the stress intensity factors along the crack front are obtained for different crack profiles. The effects of the cylinder geometry, hoop wrapped layer thickness and the property distributions of the composite layer on the stress intensity factor are discussed in detail. The numerical results show that the hoop wrapped composite cylinder can lower the stress intensity factor value greatly and ensure the safe use of pressure vessels containing defects in service. The composite property distribution owns a distinct effect on the crack behaviour in different directions that provides a clear guide to the maintenance of CNG cylinder. Finally an approximate formula with high precision is proposed to evaluate the stress intensity factor along the axial crack front in the hoop wrapped cylinder with composite layer.

14/02427 System reliability of corroding pipelines considering stochastic process-based models for defect growth and internal pressure

Zhang, S. and Zhou, W. *International Journal of Pressure Vessels and Piping*, 2013, 111–112, 120–130.

A methodology is presented to evaluate the time-dependent system reliability of pressurized pipelines that contain multiple active metal-loss corrosion defects and have been subjected to at least one inline inspection. The methodology incorporates a homogeneous gamma process-based corrosion growth model and a Poisson square wave process-based internal pressure model, and separates three distinctive failure modes, namely small leak, large leak and rupture. The hierarchical Bayesian method and Markov Chain Monte Carlo simulation are employed to characterize the parameters in the corrosion growth model based on data obtained from high-resolution inline inspections. An example involving an in-service gas pipeline is used to validate the developed corrosion growth model and illustrate the proposed methodology for the system reliability analysis. Results of the parametric analysis indicate that both the uncertainties in the parameters of the growth model as well as their correlations must be accounted for in the reliability analysis. The proposed methodology will facilitate the application of reliability-based pipeline corrosion management programmes.

Economics, business, marketing, policy

14/02428 Balancing gas supply and demand with a sustainable gas supply chain – a study based on field data

Bekkering, J. *et al. Applied Energy*, 2013, 111, 842–852.

The possibilities of balancing gas supply and demand with a green gas supply chain were analysed. The considered supply chain is based on co-digestion of cow manure and maize, the produced biogas is upgraded to (Dutch) natural gas standards. The applicability of modelling yearly gas demand data in a geographical region by Fourier analysis was investigated. For a sine shape gas demand, three scenarios were further investigated: varying biogas production in time, adding gas storage to a supply chain, and adding a second digester to the supply chain which is assumed to be switched off during the summer months. A regional gas demand modelled by a sine function is reasonable for household type of users as well as for business areas, or a mixture of those. Of the considered scenarios, gas storage is by far the most expensive. When gas demand has to be met by a green gas supply chain, flexible biogas production is an interesting option. Further research in this direction might open interesting pathways to sustainable gas supply chains.

14/02429 China's natural gas consumption and subsidies – from a sector perspective

Wang, T. and Lin, B. *Energy Policy*, 2014, 65, 541–551.

China's natural gas consumption is growing rapidly and it has being driven by economic growth, industrialization and urbanization. In addition, the country's low-carbon development strategy, government-controlled gas price, and some other factors also contribute to the surging gas consumption. This paper studies China's natural gas consumption in residential, industrial and commercial sectors. Here, the authors adopt the cointegration test and error correction model to study the relationships of explanatory factors and gas consumption of different sectors and climate factor is included into the analysis. In order to find the direction of natural gas pricing reform and establish the benchmark gas price, the authors also estimate the size of gas price subsidy by using price-gap approach. The findings were as follows. In the long term, China's residential sector is more sensitive to price than the other two. Urbanization is an important factor promoting industrial and commercial gas consumption. Prices of other energies have an influence on natural gas consumption significantly due to the substitutability between energies. The slow-moving and unsatisfying pricing reforms on refined oil and natural gas lead to positive price elasticity of natural gas in the commercial sector, which implies that a further energy price reform is still stringent for China.

14/02430 Energy characterization of CHP (combined heat and power) fuelled with hydrogen enriched natural gas blends

de Santoli, L. *et al. Energy*, 2013, 60, 13–22.

The methane enrichment with hydrogen can improve environmental and mechanical performances of an internal combustion engine. The paper presents data resulting by the experimental campaign carried out over 42 days on a demonstration commercial combined heat and power (CHP) (60 kW_{el}) fuelled with hydrogen-enriched methane blends. The tests have been carried out at partial load 55 kW_{el} with hydrogen percentages of 0%, 5% and 8%. In order to evaluate the CHP energy consumption and environmental performance, the analysis was conducted for 336 h, using a continuous flue gas analyser and two mass flow meters for hydrogen and methane. The aim of this paper is to demonstrate how the use of the hydrogen enrichment in a CHP plant represents a valid alternative to the same commercial energy systems, regarding the CO and CO_2 emissions avoidance. The data analysis shows that modifying engine settings and increasing hydrogen amount significant energy effects occur. Consequently, the CHP fuelled with mixtures provides a lower thermal power, penalizing the heat recovery efficiency. The energy losses are due to unrecovered heat which is wasted like sensible heat to the stack. This alternative feeding system was developed in order to assess the energy penalty related to this carbon avoidance technique.

14/02431 Evaluation of the effect of the Power of One campaign on natural gas consumption

Diffney, S. *et al. Energy Policy*, 2013, 62, 978–988.

This study considers an advertising campaign launched by Ireland's government to induce more energy-efficient behaviour and assesses its effect on residential natural gas consumption. The authors first analyse changes in the daily consumption of natural gas and find that advertising leaflets had a significant, but short-lived, effect on natural gas consumption. They found no persistent effect of the campaign. The authors then studied three surveys administered to 1000 consumers prior to and during the campaign. This repeated cross-section determined that the efficiency campaign has increased awareness of behaviours that curb natural gas consumption. However, no significant effect of the campaign on self-reported natural gas-saving behaviour was found.

14/02432 Improving energy efficiency of an olefin plant – a new approach

Tahouni, N. *et al. Energy Conversion and Management*, 2013, 76, 453–462.

Low-temperature gas separation processes are the most important gas separation routes. There is a complex interaction between the core process (separation columns), associated heat exchanger network and refrigeration cycles in sub-ambient processes. The aim of this paper is performing a comprehensive retrofit study of an olefin plant (as an industrial example) to improve the overall energy efficiency. In this regard, the effect of improving column operating parameters and refrigeration cycles are first evaluated separately. Then, column operating parameters and refrigeration cycles as well as heat exchanger network are optimized simultaneously using genetic algorithm or simulated annealing. Having compared all results, one can conclude that simultaneous optimization leads to higher efficiency of the overall system.

14/02433 International gas pricing in Europe and Asia: a crisis of fundamentals

Stern, J. *Energy Policy*, 2014, 64, 43–48.

In continental Europe and liquefied natural gas-importing Asia, international gas prices reflect the market fundamentals of the 1970–1990s when gas was replacing oil products and crude oil in energy balances. By the end of the 2000s, fundamentals in both these regions had changed significantly, but gas price formation mechanisms had not. This created major problems for buyers locked into long-term contracts indexed to crude oil and oil product prices, which had risen to levels far above gas market fundamentals. By 2013, the transition to hub-based pricing was well advanced in Europe and dominant in the large markets in the north-west of the continent. In Asia the 'crisis of fundamentals' was only just starting to be addressed with a transition to market pricing an urgent imperative, but still a distant prospect.

14/02434 Methods of estimating shale gas resources – comparison, evaluation and implications

McGlade, C. *et al. Energy*, 2013, 59, 116–125.

Estimates of technically recoverable shale gas resources remain highly uncertain, even in regions with a relatively long history of shale gas production. This paper examines the reasons for these uncertainties, focusing in particular on the methods used to derive resource estimates. Such estimates can be based upon the extrapolation of previous production experience in developed areas, or from the geological appraisal of undeveloped areas. The paper assesses the strengths and weaknesses of these methods, the level of uncertainty in the results and the implications of this for current policy debates. The authors conclude that there are substantial difficulties in assessing the recoverable volumes of shale gas and that current resource estimates should be treated with considerable caution. Most existing studies lack transparency or a rigorous approach to assessing uncertainty and provide estimates that are highly sensitive to key variables that are poorly defined - such as the assumed ratio of gas-in-place to recovered gas (the 'recovery factor') and the assumed ultimate recovery from individual wells. To illustrate the uncertainties both within and between different methodological approaches, case studies are provided of resource estimates for the Marcellus shale in the USA and three basins in India.

14/02435 New concept for energy storage: microwave-induced carbon gasification with CO_2

Bermúdez, J. M. *et al. Energy Conversion and Management*, 2014, 78, 559–564.

Energy storage is a topic of great importance for the development of renewable energy, since it appears to be the only solution to the problem of intermittency of production, inherent to such technologies. In this paper, a new technology for energy storage, based on microwave-induced CO_2 gasification of carbon materials is proposed. The tests carried out in this study on different carbon materials showed that charcoal consumes the least amount of energy. Two microwave heating mechanisms, a single-mode oven and a multimode device, were evaluated with the latter proving itself to be the more efficient in terms of energy consumption and recovery. The initial results obtained showed that this technology is able to achieve energy efficiencies of 45% at laboratory scale with every indication that these results can be improved upon to make this approach highly competitive against other energy storage technologies.

14/02436 Scenario analysis of nonresidential natural gas consumption in Italy

Bianco, V. *et al. Applied Energy*, 2014, 113, 392–403.

The aim of this study is to develop a model for the long-term forecasting of non-residential gas consumption in Italy. The influence of economic and climatic data, as well as the impact of regulatory changes are considered. The model is developed using a regression model and determines the necessary variable. A successful validation of the model is performed, showing that it guarantees a satisfactory level of accuracy. Short- and long-run elasticities are estimated, highlighting that gross domestic product (GDP) per capita has a much greater influence on gas consumption with respect to price. Twenty-four consumption scenarios are presented, underlining that in 2030 non-residential gas consumption in Italy is expected to be between about 32 and 46 billions of cubic metres. It can be concluded that the increase of non-residential gas consumption is strongly linked to the GDP evolution and, according to the GDP growth scenario, non-residential gas consumption might largely change. The outcomes of this analysis can be used by energy managers to design appropriate energy management policies. Particularly, the determination of the elasticities has practical relevance in setting up adequate pricing policies, whereas the long-term forecast represents a useful support to estimate the volume of the necessary supply contracts and to plan new infrastructures.

14/02437 Techno-economic analysis of RES & hydrogen technologies integration in remote island power system

Tzamalis, G. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11646–11654.

This study considers the integration of hydrogen technologies as an energy storage medium in a hybrid power system. The existing power system of the island of Milos, which is based on fossil fuel generators and a small wind park, is assessed in the context of this paper. System level simulation results, from both technical and economic point of view, are presented for the currently existing and the proposed island's hybrid power system. The latter integrates a higher number of wind turbines and hydrogen technologies as energy storage medium, and the two system architectures are being compared taking into account not only technical and economic parameters but also greenhouse gas (GHG) emissions, fossil fuels consumption and renewable energy sources (RES) penetration increase. Moreover, a sensitivity analysis has been performed in order to determine the contribution of hydrogen technologies equipment costs; with the cost of energy produced (COE) being the critical parameter. Results show that COE for the proposed power system is higher than the existing one, but on the other hand GHG emissions and fossil fuel consumption are significantly reduced. In addition, RES penetration increases dramatically and the sensitivity analysis indicates that a further reduction in hydrogen technologies equipment and subsidy on wind turbine costs would make RES and hydrogen-based systems economically competitive to the existing power system of the island.

14/02438 The Asia Pacific natural gas market: large enough for all?

Aguilera, R. F. *et al. Energy Policy*, 2014, 65, 1–6.

Among natural gas producing nations, there has been some concern about how the Asia Pacific will meet the future demand for energy. The authors argue that natural gas, both regional and global, will play an important role. Estimates of potential gas consumption in the region are analysed and used to develop consensus projections to 2030. These consumption profiles are compared with gas supply estimates including indigenous, pipeline and liquefied natural gas for the Asia Pacific market. From this analytical framework, the authors found that demand will be sufficiently large to accommodate supplies from diverse sources including North America, the Middle East, Central Asia, Russia and the Asia Pacific itself. An important policy implication is that gas producing and consuming nations should benefit from promoting gas trade and not be concerned about a situation of potential lack of demand coupled with oversupply.

14/02439 The development of natural gas as an automotive fuel in China

Ma, L. *et al. Energy Policy*, 2013, 62, 531–539.

This paper aims to systematically review the development of natural gas as an automotive fuel in China and to draw policy implications for decision making. A brief overview of natural gas development and the potential of natural gas as an automotive fuel in China is presented, followed by an introduction to the development of various technology pathways for using natural gas as an automotive fuel, including compressed natural gas (CNG) vehicles, liquefied natural gas (LNG) vehicles and others. This material suggests that there is a large potential to increase the use of natural gas as an automotive fuel, especially for CNG and LNG vehicles. The following activities will promote the development of natural gas vehicles: prioritizing vehicle use in the utilization of natural gas, supporting the construction of natural gas filling stations, developing a favourable pricing policy for natural gas used in vehicles, and enhancing the research and development to further improve the technology performance, especially for the technology of LNG vehicles.

14/02440 The impact of small scale cogeneration on the gas demand at distribution level

Vandewalle, J. and D'haeseleer, W. *Energy Conversion and Management*, 2014, 78, 137–150.

Smart grids are often regarded as an important step towards the future energy system. Combined heat and power (CHP) or cogeneration has several advantages in the context of the smart grid, which include the efficient use of primary energy and the reduction of electrical losses through transmission. However, the role of the gas network is often overlooked in this context. Therefore, this work presents an analysis of the impact of a massive implementation of small-scale (micro) cogeneration units on the gas demand at distribution level. This work shows that using generic information in the simulations overestimates the impact of CHP. Furthermore, the importance of the thermal storage tank capacity on the impact on the gas demand is shown. Larger storage tanks lead to lower gas demand peaks and hence a lower impact on the gas distribution network. It is also shown that the use of an economically led controller leads to similar results compared to classical heat led control. Finally, it results that a low sell back tariff for electricity increases the impact of cogeneration on the gas demand peak.

14/02441 The importance of economies of scale, transport costs and demand patterns in optimising hydrogen fuelling infrastructure: an exploration with SHIPMod (spatial hydrogen infrastructure planning model)

Agnolucci, P. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11189–11201.

Hydrogen is widely recognized as an important option for future road transportation, but a widespread infrastructure must be developed if the potential for hydrogen is to be achieved. This paper presents a mixed-integer linear programming model (called SHIPMod) that optimizes a hydrogen supply chains for scenarios of hydrogen fuel demand in the UK, including the spatial arrangement of carbon capture and storage infrastructure. In addition to presenting a number of improvements on past practice in the literature, the paper focuses attention on the importance of assumptions regarding hydrogen demand. The paper draws on socio-economic data to develop a spatially detailed scenario of possible hydrogen demand. It then shows that assumptions about the level and spatial dispersion of hydrogen demand have a significant impact on costs and on the choice of hydrogen production technologies and distribution mechanisms.

14/02442 Trigeneration scheme for a natural gas liquids extraction plant in the Middle East

Eveloy, V. *et al. Energy Conversion and Management*, 2014, 78, 204–218.

Natural gas processing plants in the Persian Gulf face extreme climatic conditions that constrain their gas turbine (GT) power generation and cooling capacities. However, due to a past history of low hydrocarbon prices, such plants have not fully exploited their waste heat recovery potential to date. The techno-economic performance of a combined cooling, heating and power (CCHP) scheme designed to enhance the energy efficiency of a major natural gas liquid extraction plant in the Persian Gulf is assessed. The trigeneration scheme utilizes double-effect water–lithium bromide absorption refrigeration powered by steam generated from GT exhaust gas waste heat to provide both GT compressor inlet air cooling and process gas cooling. Part of the generated steam is also used for process gas heating. Thermodynamic modelling reveals that recovery of 82 MW of GT waste heat would provide additional cooling and heating capacities of 75 and 24 MW to the plant, respectively, thereby permitting elimination of a 28 MW GT, and existing cooling and heating equipment. GT compressor inlet air cooling alone yields approximately 151 GW h of additional electric power annually, highlighting the effectiveness of absorption refrigeration in meeting compressor inlet air cooling loads throughout the year in the Gulf climate. The overall net annual operating expenditure savings contributed by the CCHP system would average approximately US$14.6 million over its lifespan, which corresponds to average yearly savings of 190 MMSCM of natural gas. The CCHP scheme economic payback period is conservatively estimated at 2.7 years based on current utility and domestic gas prices. The net present value of the CCHP system is estimated at $158 million, with an internal rate of return of 39%.

Derived gaseous fuels

14/02443 Elaboration of La$_{1-x}$Sr$_x$Fe$_{1-y}$Ga$_y$O$_{3-\delta}$ multilayer membranes by tape casting and co-firing for syngas application

Geffroy, P. M. *et al. Journal of the European Ceramic Society*, 2013, 33, (10), 1849–1858.

The decrease of the dense layer thickness can lead to increase the internal stresses in the membrane due to the chemical expansion of membrane material under a large gradient of oxygen partial pressure. This chemical expansion due to the p_{O_2} gradient through the membrane leads to important mechanical stresses in the membrane and commonly to the membrane rupture under large range of p_{O_2}, i.e. air/methane atmosphere. The solution suggested in this paper is the elaboration by tape casting and co-firing process of multilayer membranes with a specific design in order to decrease stresses due to the chemical expansion in working conditions.

14/02444 Internal and external HIDiCs (heat-integrated distillation columns) optimization by genetic algorithm

Shahandeh, H. *et al. Energy*, 2014, 64, 875–886.

The heat-integrated distillation column (HIDiC) is an effective energy-saving configuration for the separation of close boiling point mixtures. In this work, the stochastic methodology has been applied for optimization of both internal and external HIDiCs. The use of a genetic algorithm (GA) to find the optimal HIDiC configuration is presented while the fitness function is set to be the total annual cost (TAC). HIDiC simulation has been performed based on the modified MESH equations using a rigorous thermodynamic model. A novel integer variable (the layout number) is introduced, leading to a more effective solution for the examined case study. This variable can generate systematically more energy-efficient candidates for both internal and external HIDiCs. Benzene–toluene separation has been investigated by the proposed optimization procedure. The multi-variable problem can be successfully optimized by the GA while a good initial estimation is not essential. Based on the final results, up to 6.60% and 9.75% TAC reduction have been accomplished in external and internal HIDiCs using the proposed method compared to the reported solutions in a previous work for the examined case study. However, vapour recompression column optimization at the end of presented work results 7.89% TAC reduction rather than optimal HIDiC.

14/02445 Methane from benzene in argon dielectric barrier discharge

Das, T. N. and Dey, G. R. *Journal of Hazardous Materials*, 2013, 248–249, 469–477.

A first-time account of direct, on-line, instantaneous and efficient chemical conversion of gas phase benzene to methane in argon dielectric barrier discharge (DBD) is presented. In the absence of another overt hydrogen-donating source, potency of analogous parents toward methane generation is found to follow the order: benzene > toluene > *p*-xylene. Simultaneous production of trace amounts of phenolic surface deposits suggest: (a) prompt decomposition of the parent molecules, including a large fraction yielding atomic transients (H-atom), (b) continuous and appropriate recombination of such parts, and (c) trace moisture in parent contributing ·OH radicals and additional H-atoms, which suitably react with the unreacted fraction of the parent, and also other intermediates. Results highlight Ar DBD to be a simple and exploitable technology for transforming undesirable hazardous aromatics to usable/useful low molecular weight open-chain products following the principles of green chemistry and engineering.

14/02446 Multi-zone modeling and simulation of syngas combustion under laminar conditions

Monteiro, E. *et al. Applied Energy*, 2014, 114, 724–734.

The use of laminar models has been generally accepted, as quench distances in engines and the distances obtained for laminar flame quench calculations could be well correlated. In this work a multi-zone model is presented in order to derive the quenching distance and heat flux in laminar syngas–air flames based on recent developments in the science of combustion. Three typical mixtures of H_2, CO, CH_4, CO_2 and N_2 have been considered as representative of the syngas coming from wood gasification, and its laminar combustion is made in a static spherical vessel. The model is validated for the methane–air case and then applied to syngas–air mixtures in order to estimate the heat flux to the walls and quenching distances. Two wall heat transfer models are implemented and compared. The classical Woschni model based on the hypotheses of forced convection and the Rivère model based on kinetic theory of gases. The conclusion could be drawn that the Rivère heat transfer model is capable of better reproducing the heat flux to the walls. Heat flux through the walls is higher for stoichiometric syngas–air mixtures which follows the same behaviour of the pressure inside the combustion vessel. Quenching distance of syngas–air mixtures decreases with the heat flux increase, which is consistent with earlier studies. This model could be very useful in predicting the physical conditions of quenching especially for estimation of the quenching distance where the measurement is not possible such as in engines. However, the estimation given should be understood as an order of magnitude, because in turbulent conditions the flame–wall interaction results in lower Peclet numbers than in the laminar case.

14/02447 Optimization of dry reforming of methane over Ni/YSZ anodes for solid oxide fuel cells

Guerra, C. *et al. Journal of Power Sources*, 2014, 245, 154–163.

This work investigates the catalytic properties of Ni/YSZ anodes as electrodes of solid oxide fuel cells (SOFCs) to be operated under direct dry reforming of methane. The experimental test rig consists of a micro-reactor, where anode samples are characterized. The gas composition at the reactor outlet is monitored using a mass spectrometer. The kinetics of the reactions occurring over the anode is investigated by means of isotherm reactions and temperature-programmed reactions. The effect of the variation of temperature, gas residence time and inlet carbon dioxide–methane volumetric ratio is analysed. At 800 °C, the best catalytic performance (in the carbon safe region) is obtained for 1.5 < carbon dioxide/methane ratio < 2, which is an interesting result for prospective direct biogas fuelled SOFCs. Conversion is stable over a period of 70 h. Both for temperatures lower than 450 °C and for carbon dioxide–methane ratios lower than equimolar at 800 °C, conversion is poor due to low activity of the anode toward dry reforming and cracking reactions, respectively. In other ranges, dry reforming and reverse water gas shift are the dominant reactions and the inlet feed reaches almost the equilibrium condition provided that a sufficient gas residence time is obtained.

14/02448 Process modeling and thermodynamic analysis of Lurgi fixed-bed coal gasifier in an SNG plant

He, C. *et al. Applied Energy*, 2013, 111, 742–757.

This paper presents a comprehensive steady state kinetic model of a commercial-scale pressurized Lurgi fixed-bed dry bottom coal gasifier. The model is developed using the simulator Aspen Plus. Five sequential modules: drying zone, pyrolysis zone, gasification zone, combustion zone and overall heat recovery unit, are considered in the main process model. A non-linear programming (NLP) model is employed to estimate the pyrolysis products, which include char, coal gas and high-weight hydrocarbons/distillable liquids (tar, phenol, naphtha and oil). To accelerate solution convergence, an external FORTRAN subroutine is used to simulate the kinetics of the combustion and gasification processes which are formulated in terms of a series of continuous stirred-tank reactors. The model is validated with industrial data. The effects of two key operating parameters, namely oxygen/coal mass ratio and steam/coal mass ratio, on the thermodynamic efficiencies of the Lurgi gasifier and the gasification system as a whole are investigated via extensive simulation studies.

14/02449 Syngas production from downdraft gasification of oil palm fronds

Atnaw, S. M. *et al. Energy*, 2013, 61, 491–501.

Studies on the gasification of oil palm fronds are scarce, even though this biomass constitutes more than 24% of the total oil palm waste. The lack of research related to gasification of oil palm fronds (OPF) calls for a study on gasification behaviour of the fuel. In this paper, the effects of reactor temperature equivalence ratio on gas composition, calorific value and gasification efficiency of downdraft gasification of OPF were investigated. The heating value of syngas and the values of cold gas and carbon conversion efficiencies of gasification obtained were found to be comparable with woody biomass. The study showed that oxidation zone temperature above 850 °C is favourable for high concentration of the fuel components of syngas CO, H_2 and CH_4. Average syngas lower heating value of 5.2 MJ/N m^3 was obtained for operation with oxidation zone temperatures above 1000 °C, while no significant change in heating value was observed for temperature higher than 1100 °C. The average and peak heating values of 4.8 and 5.5 MJ/N m^3, and cold gas efficiency of 70.2% at optimum equivalence ratio of 0.37 showed that OPF have a high potential as a fuel for gasification.

14/02450 Thermodynamic analysis of biomass gasification with CO_2 recycle for synthesis gas production

Chaiwatanodom, P. *et al. Applied Energy*, 2014, 114, 10–17.

Thermodynamic analysis of biomass gasification with recycled CO_2 was investigated in this work to determine optimum operation mode and CO_2/C ratio. Gasification system efficiency (GSE), which takes into account the energy demand in the system, and CO_2 emissions per syngas production (CO_2/Sg) were calculated to evaluate the performance of the gasification system. Considering the production of syngas at a H_2/CO ratio of 1.5, it was revealed that indirect gasification using biomass as a fuel is the most efficient and environmental-friendly operation mode. The recycled CO_2 increases the syngas production. However, when considering the additional energy demand required for processing the recycled CO_2, it was demonstrated that there are only some ranges of operating conditions (high pressure and low temperature) which offer benefits for CO_2 recycling. The optimum CO_2/C was reported to be around 0.1–0.2 for pressurized and low temperature gasification.

LNG

14/02451 A dispersion safety factor for LNG vapor clouds

Vílchez, J. A. *et al. Journal of Hazardous Materials*, 2013, 246–247, 181–188.

The growing importance of liquefied natural gas (LNG) to global energy demand has increased interest in the possible hazards associated with its storage and transportation. Concerning the event of an LNG spill, a study was performed on the relationship between the distance at which the lower flammability limit concentration occurs and that corresponding to the visible contour of LNG vapour clouds. A parameter called the dispersion safety factor (DSF) has been defined as the ratio between these two lengths, and two expressions are proposed to estimate it. During an emergency, the DSF can be a helpful parameter to indicate the danger of cloud ignition and flash fire.

14/02452 Advanced exergetic analysis of five natural gas liquefaction processes

Vatani, A. *et al. Energy Conversion and Management*, 2014, 78, 720–737.

Conventional exergy analysis cannot identify avoidable inefficiencies. Also, this analysis does not have the ability to calculate a portion of exergy destruction which has been produced through the performance of a single component. In this study, advanced exergetic analysis was performed for five mixed refrigerant liquefied natural gas processes and four parts of irreversibility (avoidable/unavoidable) and (endogenous/exogenous) were calculated for the components with high inefficiencies. The results showed that portion of endogenous exergy destruction in the components is higher than the exogenous one. In fact, interactions among the components do not affect the inefficiencies significantly. Also, this analysis showed that structural optimization is not useful in decreasing the overall process irreversibilities. In compressors, a high portion of the exergy destruction is avoidable, thus they have a high potential to improve. But in multi-stream heat exchangers and air coolers, unavoidable inefficiencies were higher than the other parts. Advanced exergetic analysis can identify the potentials and strategies to improve thermodynamic performance of energy intensive processes.

14/02453 Analysis and optimization of cascade Rankine cycle for liquefied natural gas cold energy recovery

Choi, I.-H. *et al. Energy*, 2013, 61, 179–195.

This study proposes a new concept called the cascade Rankine cycle, which recovers liquefied natural gas cold energy for power generation, optimizes the cycle by investigating the effects of key parameters on its performance, and compares its thermal efficiency, exergy efficiency and economic evaluation to those of the conventional alternatives. The cascade Rankine cycle consists of multiple stages of the organic Rankine cycle in a layered structure in which the first stage encompasses the second one that, in turn, encompasses the next. Due to its layered configuration, optimization of the cycle is straightforward and involves sequentially optimizing the individual stages. Optimization of the subsequent stages, however, required process simulation considering the equipment efficiency and the thermodynamic properties of the working fluid. Process simulation indicated that the indicators such as net power output, thermal efficiency, and exergy efficiency generally increase as the number of stages increases. These indicators were, however, significantly affected by the thermodynamic properties of the working fluids. The proposed cycles demonstrated significantly better performance in these indicators than the conventional cycles. The three-stage cascade Rankine cycle with propane as the working fluid exhibited the highest net power output, thermal efficiency and exergy efficiency within the set.

14/02454 Automatically varying the composition of a mixed refrigerant solution for single mixed refrigerant LNG (liquefied natural gas) process at changing working conditions

Xu, X. *et al. Energy*, 2014, 64, 931–941.

The single mixed-refrigerant (SMR) process is widely used in the small- and medium-scale liquefaction of natural gas. Operating the mixed-refrigerant process outside of the design specifications is difficult but essential to save energy. Nevertheless, it is difficult to realize because the process needs to alter the working refrigerant composition. To address this challenge, this study investigated the performance diagnosis mechanism for the SMR process. A control strategy was proposed to control the changes in working refrigerant composition under different working conditions. This strategy separates the working refrigerant flow in the SMR process into three flows through two-phase separators before it flows into the cold box. The first liquid flow is rich in the high-temperature component (isopentane). The second liquid flow is rich in the middle-temperature components (ethylene and propane), and the gas flow is rich in the low-temperature components (nitrogen and methane). By adjusting the flow rates, it is easy to decouple the control variables and automate the system. Finally, this approach was validated by process simulation and shown to be highly adaptive and exergy efficient in response to changing working conditions.

14/02455 Knowledge based decision making method for the selection of mixed refrigerant systems for energy efficient LNG processes

Khan, M. S. *et al. Applied Energy*, 2013, 111, 1018–1031.

Mixed refrigerant (MR) systems are used in many industrial applications because of their high energy efficiency, compact design and energy-efficient heat transfer compared to other processes operating with pure refrigerants. The performance of MR systems depends strongly on the optimum refrigerant composition, which is difficult to obtain. This paper proposes a simple and practical method for selecting the appropriate refrigerant composition, which was inspired by (i) knowledge of the boiling point difference in MR components, and (ii) their specific refrigeration effect in bringing a MR system close to reversible operation. A feasibility plot and composite curves were used for full enforcement of the approach temperature. The proposed knowledge-based optimization approach was described and applied to a single MR and a propane precooled MR system for natural gas liquefaction. Maximization of the heat exchanger exergy efficiency was considered as the optimization objective to achieve an energy efficient design goal. Several case studies on single MR and propane precooled MR processes were performed to show the effectiveness of the proposed method. The application of the proposed method is not restricted to liquefiers, and can be applied to any refrigerator and cryogenic cooler where a MR is involved.

14/02456 New procedure for optimal design and evaluation of cogeneration system based on advanced exergoeconomic and exergoenvironmental analyses

Manesh, M. H. K. *et al. Energy*, 2013, 59, 314–333.

A systematic procedure is introduced for optimal design and evaluation of cogeneration systems based on the accurate cogeneration targeting model and the development of the *R*-curve concept through advanced exergetic, exergoeconomic and exergoenvironmental analyses. An advanced exergetic analysis makes this information more accurate and useful and supplies additional information that cannot be provided by the conventional analysis. Moreover, new graphical representations are proposed based on new concept. Finally, the optimal design of an Iranian liquefied natural gas cogeneration plant is performed, in which the usefulness of this method is clearly demonstrated.

14/02457 Uncertainty techniques in liquefied natural gas (LNG) dispersion calculations

Siuta, D. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 418–426.

The dynamic development of the liquefied natural gas (LNG) sector increases the risk of major accidents. Uncontrolled releases of LNG during the processes of manufacturing, distribution, storage, and regasification can pose a serious threat to people, facilities, and the environment. Therefore, an important goal is to determine hazard zones and the extent of potential consequences associated with a release of LNG. The key issue is to estimate these with the least level of uncertainty. The largest part of uncertainty comes from the modelling of LNG release sources and performing dispersion calculations. It is connected with the application of different mathematical models, the adoption of a number of simplifying assumptions, approximations, empirical relations, constants, and a lack of knowledge. This paper proposes a general procedure for calculating the release rate and duration time of the LNG release, pool spreading, vaporization, as well as dispersion, taking into consideration the uncertainty. The procedure consists of two parts. The first part concerns the sensitivity analysis to identify the most uncertain parameters of the LNG source term and dispersion models. The second part applies to two techniques used to include the uncertainty aspects of fuzzy sets and the Monte Carlo method for calculating hazard zones. In order to provide a basis for comparison between these two approaches, the shape of the membership functions used in the fuzzy methods are the same as the shape of the probability density function used in the Monte Carlo simulation. The case study, concerning an LNG release, illustrates the application of the proposed techniques.

14/02458 Using cryogenic exergy of liquefied natural gas for electricity production with the Stirling cycle

Dong, H. *et al. Energy*, 2013, 63, 10–18.

Cryogenic generation is one of the most important ways to utilize cold energy during liquefied natural gas (LNG) regasification. This paper fundamentally investigates LNG cryogenic generation with the Stirling cycle method based on previous studies. A basic process of LNG cryogenic generation with the Stirling cycle was presented initially with seawater and LNG as heat source and heat sink. And its thermodynamic analysis was performed to verify the theoretical feasibility of the Stirling cycle method. The generating capacity, the exergy efficiency and the cold energy utilization efficiency of the basic process were also calculated. Subsequently, the influences of evaporation pressure on net work, equipment performance and comprehensive efficiency of cold energy utilization were discussed and the effect of LNG mass flow as well as the ambient temperature was also studied. Finally, an improved process of LNG cryogenic generation with Stirling cycle method combined with an air liquefaction process is proposed as feasibility in improvements of the basic process.

Hydrogen generation and storage

14/02459 A comprehensive energy–exergy-based assessment and parametric study of a hydrogen production process using steam glycerol reforming

Hajjaji, N. *et al. Energy*, 2014, 64, 473–483.

Various assessment tools are applied to comprehensively investigate a glycerol-to-hydrogen production system. These tools investigate the chemical reactions, design and simulate the entire hydrogen production process, study the energetic and exergetic performances and perform parametric analyses (using intuitive and design of experiment-based methods). Investigating the chemical reaction of steam glycerol reforming reveals that the optimal conditions, determined based on maximizing the hydrogen production while minimizing the methane and carbon monoxide contents and coke formation, can be achieved at a reforming temperature and a water-to-glycerol feed ratio (WGFR) of 950 K and 9, respectively. The thermal and exergetic efficiencies of the resulting process are 66.6% and 59.9%, respectively. These findings are lower than those cited in the literature and relative to other reformates (methane, ethanol and methanol). The parametric investigation indicates that the performance of the process (energetic and exergetic) could be ensured by using an appropriate and judiciously selected combination of the reactor temperature and WGFR. Based on the parametric energetic and exergetic investigation, WGFR = 6 and $T = 1100$ K appear to be the most accurate parameters for the entire glycerol-to-hydrogen process. For this recommend configuration, the thermal and exergetic efficiencies are 78.1% and 66.1%, respectively.

14/02460 Activity of Ni–Cu–Al based catalyst for renewable hydrogen production from steam reforming of glycerol

Dou, B. *et al. Energy Conversion and Management*, 2014, 78, 253–259.

The activity of a Ni–Cu–Al-based catalyst for renewable hydrogen production from glycerol steam reforming has been evaluated in a continuous flow fixed-bed reactor under atmospheric pressure at 500–600 °C. The catalyst synthesized by the co-precipitation method with rising pH technique was characterized by the elemental analysis, Brenauer–Emmett–Teller adsorption method, X-ray diffraction, scanning electron microscopy, transmission electron microscopy and thermogravimetric analysis (TGA). The thermodynamic analysis for glycerol steam reforming was conducted by using a non-stoichiometric methodology based on the minimization of Gibbs free energy. The obtained results revealed that the great quantity of hydrogen is produced at excess water and the formations of CH_4 and CO in the glycerol steam reforming were almost negligible. The deactivation of catalyst due to the formation of carbon residues was observed. The carbons removal was measured by TGA during medium temperature oxidation conditions. The kinetics on glycerol steam reforming were described by means of the separability concept of reaction rate law and deactivation model, and the kinetic parameters were calculated.

14/02461 Clean hydrogen generation through the electrocatalytic oxidation of ethanol in a proton exchange membrane electrolysis cell (PEMEC): effect of the nature and structure of the catalytic anode

Lamy, C. *et al. Journal of Power Sources*, 2014, 245, 927–936.

The electrocatalytic oxidation of ethanol was investigated in a proton exchange membrane electrolysis cell (PEMEC) working at low temperature (20°C) on several Pt-based catalysts (Pt/C, PtSn/C, PtSnRu/C) in order to produce very clean hydrogen by electrolysis of a biomass compound. The electrocatalytic activity was determined by cyclic voltammetry and the rate of hydrogen evolution was measured for each catalyst at different current densities. The cell voltages U_{EtOH} were recorded as a function of time for each current density. At $100\,\mathrm{mA\,cm^{-2}}$, i.e. 0.5 A with the $5\,\mathrm{cm^2}$ surface area PEMEC used, the cell voltage did not exceed 0.9 V for an evolution rate of about $220\,\mathrm{cm^3}$ of hydrogen per hour and the electrical energy consumed was less than $2.3\,\mathrm{kWh\,(Nm^3)^{-1}}$, i.e. less than one half of the energy needed for water electrolysis ($4.7\,\mathrm{kWh\,(N\,m^3)^{-1}}$ at $U_{\mathrm{H2O}} = 2\,\mathrm{V}$). This result is valid for the decomposition of any organic compound, particularly those originated from biomass resource, provided that their electro-oxidation rate is sufficient ($>100\,\mathrm{mA\,cm^{-2}}$) at a relatively low cell voltage ($U_{\mathrm{cell}} < 1\,\mathrm{V}$) which necessitates the development of efficient electrocatalysts for the electrochemical decomposition of this compound.

14/02462 Hydrogen production by onboard gasoline processing – process simulation and optimization

Bisaria, V. and Smith, R. J. B. *Energy Conversion and Management*, 2013, 76, 746–752.

Fuel cell vehicles have reached the commercialization stage and hybrid vehicles are already on the road. While hydrogen storage and infrastructure remain critical issues in standalone commercialization of the technology, researchers are developing on-board fuel processors, which can convert a variety of fuels into hydrogen to power these fuel cell vehicles. The feasibility study of a 100 kW on-board fuel processor based on gasoline fuel is carried out using process simulation. The steady-state model has been developed with the help of Aspen HYSYS to analyse the fuel processor and total system performance. The components of the fuel processor are the fuel reforming unit, CO clean-up unit and auxiliary units. Optimization studies were carried out by analysing the influence of various operating parameters such as oxygen-to-carbon ratio, steam-to-carbon ratio, temperature and pressure on the process equipment. From the steady-state model optimization using Aspen HYSYS, an optimized reaction composition in terms of hydrogen production and carbon monoxide concentration corresponds to: oxygen-to-carbon ratio of 0.5 and steam-to-carbon ratio of 0.5. The fuel processor efficiency of 95.98% is obtained under these optimized conditions. The heat integration of the system using the composite curve, grand composite curve and utility composite curve were studied for the system. The most appropriate heat exchanger network from the generated ones was chosen and that was incorporated into the optimized flow sheet of the 100 kW fuel processor. A completely heat integrated 100 kW fuel processor flow sheet using gasoline as fuel was thus successfully simulated and optimized.

14/02463 Hydrogen production in a light-driven photoelectrochemical cell

He, Y.-R. *et al. Applied Energy*, 2014, 113, 164–168.

Conversion of organic matter to hydrogen in a microbial electrolysis cell (MEC) is one of promising ways for hydrogen generation. However, the lack of efficient and cost-effective cathode catalysts and the need of additional electricity input make it less attractive. To resolve these problems, in this work a light-driven microbial photoelectrochemical cell (MPC) system, which consists of a TiO_2 photocathode and a microbial anode, was constructed to utilize light energy and harvest electrons, respectively. In this MPC system, continuous hydrogen production was achieved without external applied voltage under UV irradiation, and it had worked well continuously over 200 h in a batch-fed mode under light illumination. An average hydrogen production rate of 3.5 μmol/h was obtained. The results are useful for designing new hydrogen-harvesting systems.

14/02464 Hydrogen yields from water on the surface of plutonium dioxide

Sims, H. E. *et al. Journal of Nuclear Materials*, 2013, 437, (1–3), 359–364.

The long-term storage of separated plutonium dioxide (PuO_2) in sealed canisters requires an understanding of the processes occurring within the cans. This includes potential mechanisms that lead to can pressurization, including the radiolysis of adsorbed water-forming hydrogen. New measurements of H_2 production rates from three sources of PuO_2 show low rates at low water monolayer coverage but a sharp increase between 75% and 95% relative humidity. This behaviour being quite different to that reported for CeO_2 and UO_2, which, therefore, cannot be considered as suitable analogues for PuO_2/H_2O radiation chemistry. It is concluded that surface recombination reactions are likely to be important in the radiation chemistry and that the H_2 production arises from a radiolytic process and not a thermal reaction, at least in these experiments.

14/02465 Improving hydrogen generation from kitchen wastes by microbial acetate tolerance response

Zhao, M.-X. and Ruan, W.-Q. *Energy Conversion and Management*, 2014, 77, 419–423.

The microbial acid tolerance response (ATR) was adopted to improve the hydrogen yield by relieving the organic acids inhibition. The results indicated that the hydrogen generation from kitchen wastes could be enhanced with the acetic acid stress of 6.0 g/L, and it reached 68.3 mL/gVS, which was 2.09 times the control. The improvement was due to the increase of acetic acid tolerance with more ATR induction, since the increase of hydrogen yield was positive correlation with the concentration of acetic acid. H^+-ATPase activity system played an important role in the ATR. It reached maximum of 132.4 U/gTS at 6.0 g/L stress, which was 45.2% higher than the control. Dehydrogenase enzyme in 6.0 g/L group improved of 50.6% than the control, and it could indicate the microbial activity during hydrogen generation process.

14/02466 Optimization of hydrogen production in in-situ catalytic adsorption (ICA) steam gasification based on response surface methodology

Yusup, S. *et al. Biomass and Bioenergy*, 2014, 60, 98–107.

The present study investigates the optimization of hydrogen (H_2) production with *in situ* catalytic adsorption steam gasification by using a pilot-scale fluidized bed gasifier. Two important response variables, i.e. H_2 composition (in percentage volume fraction, %) and H_2 yield (in $g\,kg^{-1}$ of biomass) are optimized with respect to five process variables such as temperature (600–750 °C), steam-to-biomass mass ratio (1.5–2.5), adsorbent-to-biomass mass ratio (0.5–1.5), superficial velocity ($0.15–0.26\,m\,s^{-1}$) and biomass particle size (350 μm to 2 mm). The optimization study is carried out based on response surface methodology using the central composite rotatable design approach. The adsorbent-to-biomass mass ratio is found to be the most significant process variables that influenced the H_2 composition, whereas temperature and biomass particle size are found to be marginally significant. For H_2 yield, temperature is the most significant process variables followed by steam-to-biomass mass ratio, adsorbent-to-biomass mass ratio and biomass particle size. The optimum process conditions are found to be at 675 °C, steam-to-biomass mass ratio of 2.0, adsorbent-to-biomass mass ratio of 1.0, superficial velocity of $0.21\,m\,s^{-1}$ that is equivalent to four times the minimum fluidization velocity, and 1.0–2.0 mm of biomass particle size. The theoretical response variables predicted by the developed model fit well with the experimental results.

14/02467 Process design of a hydrogen production plant from natural gas with CO_2 capture based on a novel Ca/Cu chemical loop

Martínez, I. *et al. Applied Energy*, 2014, 114, 192–208.

A detailed and comprehensive design of a H_2 production plant based on a novel Ca/Cu chemical looping process is presented. This H_2 production process is based on the sorption-enhanced reforming concept using natural gas together with a $CaO/CaCO_3$ chemical loop. A second Cu/CuO loop is incorporated to supply energy for the calcination of the $CaCO_3$ via the reduction of CuO with a fuel gas. A comprehensive energy integration description of the different gas streams available in the plant is provided to allow a thermodynamic assessment of the process and to highlight its advantages and drawbacks. Hydrogen equivalent efficiencies of up to 77% are feasible with this novel Ca/Cu looping process, using an active reforming catalyst based on Pt, high oxidation temperatures and moderate gas velocities in the fixed bed system, which are around 6% points above the efficiency of a reference H_2 production plant based on conventional steam reforming including CO_2 capture with methyldiethanolamine (MDEA). Non-converted carbon compounds in the reforming stage are removed as CO_2 in the calcination stage of the Ca/Cu looping process, which will be compressed and sent for storage. Carbon capture efficiencies of around 94% can be obtained with this Ca/Cu looping process, which are significantly higher than those obtained in the reference plant that uses MDEA absorption (around 85%). Additional advantages, such as its compact design and the use of cheaper materials compared to other commercial processes for H_2 production with CO_2 capture, confirm the potential of the Ca/Cu looping process as a pre-combustion CO_2 capture technology for H_2 production.

14/02468 Progress in polymeric material for hydrogen storage application in middle conditions

Pedicini, R. *et al. Energy*, 2014, 64, 607–614.

Hydrogen sorption using a manganese oxide anchored to a polyether ether ketone matrix was studied. The functionalization process and the obtained results on hydrogen storage capability of the synthesized polymer are reported. The functionalized polymer was characterized by scanning electron microscopy, transmission electron microscopy, X-ray diffraction and volumetric hydrogen sorption measurements. Different synthesis conditions in terms of precursor concentration and reaction time were used and the direct correlation between manganese oxide percentage and hydrogen storage capability was confirmed. In this way different powders were synthesized. It is assumed that the sample with 78 wt% (SPMnO6) forms a combination of mixed manganese oxides since different reticular planes were observed. On this sample, promising results regarding to hydrogen capability at 110 °C and 60 bar were obtained, in particular 1.1 wt% hydrogen sorption was recorded. Moreover, this value, after about 30 h, remains quite constant. These preliminary results demonstrate the capability of such compound to absorb hydrogen, for this reason further morphological and structural studies are in progress with the aim to better understand the mechanism involving the storage.

14/02469 Recent advances in understanding of flammability characteristics of hydrogen

Sánchez, A. L. and Williams, F. A. *Progress in Energy and Combustion Science*, 2014, 41, 1–55.

The increasing interest in hydrogen use and hydrogen combustion prompted this review of the flammability characteristics of hydrogen. The study begins with an updated investigation of the elementary chemical mechanism of hydrogen oxidation, including the latest chemical-kinetic results, with evaluated selections of reaction-rate parameters. Understanding of the mechanism is emphasized through presentation of systematically reduced overall steps and their associated rates. Useful simplifications of the chemistry are thereby exposed and appraised, identifying applicable quasi-steady-state approximations. The status of knowledge of the fundamental transport properties for hydrogen combustion is then summarized, with indication of the relevance of thermal diffusion for hydrogen. Hydrogen–oxygen autoignition processes are next analysed, including the important differences found under conditions above and below the crossover temperature at which the rates of the branching and recombination steps are equal, with an explanation of the classical explosion diagram that exhibits three explosion limits. Time-dependent and counter-flow mixing layers are addressed in the context of ignition processes. Knowledge of hydrogen deflagrations is reviewed, including their flame structures, burning velocities, and flammability limits, with special emphasis on peculiarities and simplification that occur in the vicinity of the lean limit. Deflagration instabilities and effects of strain and curvature on deflagrations are described, resulting under appropriate circumstances in flame balls, the structures, characteristics, and importance of which are analysed. The structures and stabilization mechanisms of hydrogen diffusion flames are reviewed, pointing out the current state of knowledge and current uncertainties in their extinction conditions. Hydrogen detonations also are considered, with explanations given of their detonation velocities, structures, and instabilities, including cellular detonations and emphasizing the importance of future studies of vibrational relaxation effects in these detonations. Finally, some comments and observations on the applications and future prospects for hydrogen usage are offered from viewpoints of safety and energy production.

14/02470 Synthesis of hydrogen and carbon nanotubes over copper promoted Ni/SiO_2 catalyst by thermocatalytic decomposition of methane

Saraswat, S. K. and Pant, K. K. *Journal of Natural Gas Science and Engineering*, 2013, 13, 52–59.

This work presents thermocatalytic decomposition of methane for the production of hydrogen and carbon nanotubes over Ni and Cu promoted Ni catalysts synthesized by wet impregnation method using SiO_2 support. Effect of important parameters such as reaction temperature, metal loading, Ni/Cu ratio and gas hourly space velocity (GHSV) on methane decomposition and hydrogen yields were examined. Incorporation of copper on nickel leads to an increase in the methane conversion/hydrogen yield. Among the various catalysts tested, 50%Ni–10%Cu/SiO_2 catalyst resulted in highest activity in terms of methane conversion and carbon yield, however catalytic activities decreased rapidly at high promoter (Cu/Ni) ratio. Effect of regenerated catalysts showed no significant decrease in methane conversion up to second cycles of regeneration. Decrease in the space velocity of methane was favourable to promote the methane conversion. The structural and morphological nature of the calcined and spent catalyst was performed by Brunauer–Emmett–Teller surface area, temperature-programmed reduction, chemisorption, X-ray diffraction, thermogravimetric, scanning electron microscopy and transmission electron microscopy analysis.

14/02471 Thermal processing of plastics from waste electrical and electronic equipment for hydrogen production

Acomb, J. C. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 320–327.

Plastic waste from waste electrical and electronic equipment (WEEE) produced from a real-world commercial WEEE recycling centre has been processed using pyrolysis–gasification using a two-stage reaction system to produce hydrogen. In the first stage, the plastic fraction was pyrolysed at 600 °C and the evolved pyrolysis gases were passed directly to a second reactor at 800 °C and reacted with steam in the presence of a Ni/Al_2O_3 catalyst. In addition, high impact polystyrene (HIPS) and acrylonitrile–butadiene–styrene (ABS) which were the main components of the WEEE plastic were reacted to compare with the WEEE plastic. The results showed that the introduction of steam and the catalyst increased the yield of hydrogen. Increasing the nickel content in the catalyst also resulted in higher hydrogen yield. The comparison of the results of WEEE with those of HIPS and ABS showed that WEEE plastic was mainly composed of ABS. The catalyst, after reaction, showed significant deposition of coke composed of filamentous and layered type carbon. Overall the novel processing of waste plastic from electrical and electronic equipment using a two stage pyrolysis–gasification reactor shows great promise for the production of hydrogen.

14/02472 Thermodynamic analysis of chemical-looping hydrogen generation

Zhang, X. and Jin, H. *Applied Energy*, 2013, 112, 800–807.

Recently, interest in chemical-looping combustion (CLC) has grown because it is a technique that could allow cost-effective carbon capture and storage. Recently, the chemical-looping process was also proposed for the production of hydrogen. Chemical-looping hydrogen (CLH) generation, which is a derivation of CLC, is a water-splitting process that involves the reduction–oxidation of a metal oxide. CLC and CLH can reduce the irreversibility and the extent of heat rejection, thereby improving the cycle efficiency. The current paper presents a thermodynamic analysis of CLH to illustrate its potential for improved efficiency. A methodology for selecting oxygen carriers based on their thermodynamic properties is developed, and several candidate materials are reviewed. From a thermodynamic perspective, metals such as Ni and Fe are more suitable for CLH, whereas metals such as Ca and Cd can provide higher efficiency for CLC. Finally, comments on the practical implementations of CLH in power plants are presented.

14/02473 Which of the technologies for producing hydrogen is the most prospective in Korea?: evaluating the competitive priority of those in near-, mid-, and long-term

Chung, Y. *et al. Energy Policy*, 2014, 65, 115–125.

In order to evaluate the alternative technologies for producing hydrogen in Korea stage by stage, this study determined impact factors, calculated their weights and evaluated the hydrogen production technologies in Korea using the analytic hierarchy process (AHP) approach. The AHP is a useful method for resolving multi-criteria decision-making problems. The study investigated four criteria (technical characteristics, economic efficiency, marketability, internal capability) and 11 sub-criteria (scale, efficiency, key barriers, carbon dioxide reduction, current production cost, expected production cost in 2017, feed-stock, technical maturity, R&D competitive level, technology gap with competing agencies and domestic infrastructure). The alternatives are natural gas reforming technology, coal gasification technology, biomass gasification technology, water electrolysis technology, thermochemical production technology, photoelectrochemical hydrogen production technology and biological hydrogen production technology. In order to maintain the objectivity of the analysis result and observe the difference among the groups, the questionnaire survey targets were divided into the R&D professional group and policy professional group. This result of the study is expected to serve as important basic information in the establishment of a national R&D strategy to prepare for the imminent hydrogen economy era.

04 BY-PRODUCTS RELATED TO FUELS

14/02474 Characteristics of activated carbon prepared from waste PET by carbon dioxide activation

Bratek, W. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 192–198.

Poly(ethylene)terephthalate (PET) waste was subjected to carbonization in a nitrogen stream at 1098 K. The coke was then activated in a carbon dioxide stream under various conditions: temperatures of 1173, 1198 and 1213 K as well as process times of 4, 5, 6 and 8 h. The activated carbons were characterized using various methods: the structure from Raman and X-ray diffraction measurements, the porosity from low temperature nitrogen adsorption, the surface properties from cyclic voltammetry and the hydrogen storage capacity from the low temperature adsorption isotherm of H_2. The results demonstrated the importance of the temperature and the duration of the process. Higher temperatures result in the etching of graphitic domains of better crystallinity. A relatively small increase in activation time at the highest temperature used yielded a significant increase in the degree of burn-off and porous structure development. The microporosity of these carbons is similar to that of commercial activated carbons. They also have a similar capacity to adsorb water pollutants (e.g. 4-chlorophenol). The PET carbon sample with maximum burn-off exhibited higher values of the microporous structure parameters and the electric double layer capacity in electrolyte solution than the other three samples. The same sample exhibits a sufficient hydrogen storage capacity, which after optimization of the activation conditions should yield an effective storage material. This confirms the possibility of producing activated carbon from waste PET with satisfactory properties by the simple processes of carbonization and activation. The activated carbons obtained have potential use as water pollutant adsorbents, low-cost materials for hydrogen storage and electrode materials in supercapacitors or fuel cells.

14/02475 Electrodialytic removal of Cd from biomass combustion fly ash suspensions

Kirkelund, G. M. *et al. Journal of Hazardous Materials*, 2013, 250–251, 212–219.

Due to relatively high concentrations of Cd, biomass combustion fly ashes often fail to meet Danish legislative requirements for recycling as fertilizer. In this study, the potential of using electrodialytic remediation for removal of Cd from four different biomass combustion fly ashes was investigated with the aim of enabling reuse of the ashes. The ashes originated from combustion of straw (two ashes), wood chips, and co-firing of wood pellets and fuel oil, respectively. A series of laboratory-scale electrodialytic remediation experiments were conducted with each ash. The initial Cd concentration in the ashes varied between 8.8 mg Cd/kg (co-firing ash) and 64 mg Cd/kg (pre-washed straw ash), and pH varied from 3.7 (co-firing ash) to 13.3 (wood ash). In spite of such large variations between the ashes, the electrodialytic method showed to be sufficiently robust to treat the ashes so the final Cd concentration was below 2.0 mg Cd/kg DM in at least one experiment done with each ash. This was obtained within 2 weeks of remediation and at liquid-to-solid (L/S) ratios of L/S 16 for the pre-washed straw ash and L/S 8 for the straw, co-firing and wood ash.

14/02476 The effects of a microwave heating method on the production of activated carbon from agricultural waste: a review

Hesas, R. H. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 1–11.

A review of the effect of a microwave treatment on the production of activated carbon (AC) from agricultural waste is presented in this study. Although the thermal heating method is one of the most usual and applicable methods for the production of AC, this method has some disadvantages such as a thermal gradient from the surface to the interior of a particle, high cost of heating, long preparation time and fast firing. A microwave radiation method has been used recently by many researchers as an alternative method for heating. In this review, these two different methods of producing AC were compared. Previous studies on the preparation of AC using a microwave radiation method showed that the more significant parameters are the microwave radiation time, the microwave power level, the impregnation ratio and the agent flow rate. Accordingly, in this review, the effects of these parameters on the physical and chemical properties of AC, such as the pore structure, the adsorption capacity, the carbon yield and the surface functional groups, were discussed. In general, the physical properties of AC (adsorption capacity, pore volume and carbon yield) improved when these parameters were enhanced up to their optimum points, and then these properties decreased when these parameters were increased beyond their optimum values. The carbon/oxygen ratio was increased by the microwave method due to the elimination of acidic oxygen-containing functional groups on the surfaces of the ACs.

14/02477 Yield and characteristics of shale oil from the retorting of oil shale and fine oil-shale ash mixtures

Niu, M. *et al. Applied Energy*, 2013, 111, 234–239.

For exploring and optimizing the oil shale fluidized bed retort with fine oil-shale ash as a solid heat carrier, retorting experiments of oil shale and fine oil-shale ash mixtures were conducted in a laboratory-scale retorting reactor to investigate the effects of fine oil-shale ash on shale oil. Oil shale samples were obtained from Dachengzi Mine, China, and mixed with fine oil-shale ash in the ash/shale mass ratios of 0 : 1, 1 : 4, 1 : 2, 1 : 1, 2 : 1 and 4 : 1. The experimental retorting temperature was enhanced from room temperature to $520\,^{\circ}\mathrm{C}$ and the average heating rate was $12\,^{\circ}\mathrm{C\,min^{-1}}$. It was found that, with the increase of the oil-shale ash fraction, the shale oil yield first increased and then obviously decreased, whereas the gas yield appeared conversely. Shale oil was analysed for the elemental analysis, presenting its atomic H/C ratio of 1.78–1.87. Further, extraction and simulated distillation of shale oil were also conducted to explore the quality of shale oil. As a result, the ash/shale mixing mass ratio of 1 : 2 was recommended only for the consideration of increasing the yield and quality of shale oil.

05 NUCLEAR FUELS

Scientific, technical

14/02478 A modeling and control approach to advanced nuclear power plants with gas turbines

Ablay, G. *Energy Conversion and Management*, 2013, 76, 899–909.

Advanced nuclear power plants are currently being proposed with a number of various designs. However, there is a lack of modelling and control strategies to deal with load-following operations. This research investigates a possible modelling approach and load-following control strategy for gas turbine nuclear power plants in order to provide concept designs. A load frequency control strategy and average temperature control mechanism are studied to find load-following nuclear power plants. The suitability of the control strategies and concept designs are assessed through linear stability analysis methods. Numerical results are presented on an advanced molten salt reactor concept as an example nuclear power plant system to demonstrate the validity and effectiveness of the proposed modelling and load-following control strategies.

14/02479 Adsorption of uranium from aqueous solution by PAMAM dendron functionalized styrene divinylbenzene

Ilaiyaraja, P. *et al. Journal of Hazardous Materials*, 2013, 250–251, 155–166.

A new polymeric chelating resin was prepared by growing third-generation poly(amido)amine (PAMAMG$_3$) dendron on the surface of styrene divinylbenzene (SDB) and characterized by Fourier transform infrared spectroscopy, thermogravimetric analysis and scanning electron microscopy. The ideal branching of dendron in the chelating resin was determined from potentiometric titration. Adsorption of uranium(VI) from aqueous solution using PAMAMG$_3$-SDB chelating resin was studied in a series of batch experiments. Effect of contact time, pH, ionic strength, adsorbent dose, initial U(VI) concentration, dendron generation and temperature on adsorption of U(VI) were investigated. Kinetic experiments showed that U(VI) adsorption on PAMAMG$_3$-SDB followed pseudo-second-order kinetics model appropriately and equilibrium data agreed well with the Langmuir isotherm model. Thermodynamic parameters (ΔH°, ΔS°, ΔG°) were evaluated from temperature-dependent adsorption data and the uranium adsorption on PAMAMG$_3$-SDB was found to be endothermic and spontaneous in nature. The sticking probability value (5.303×10^{-9}), kinetic and isotherm data reveal the chemisorption of uranium on PAMAMG$_3$-SDB and adsorption capacity of the chelating resin was estimated to be $130.25\,\mathrm{mg\,g^{-1}}$ at 298 K. About 99% of adsorbed U(VI) can be desorbed from PAMAMG$_3$-SDB by a simple acid treatment suggesting that the chelating resin is reusable.

14/02480 An exergoeconomic investigation of waste heat recovery from the gas turbine-modular helium reactor (GT-MHR) employing an ammonia–water power/cooling cycle

Zare, V. *et al. Energy*, 2013, 61, 397–409.

A detailed exergoeconomic analysis is performed for a combined cycle in which the waste heat from the gas turbine–modular helium reactor (GT-MHR) is recovered by an ammonia–water power/cooling cogeneration system. Parametric investigations are conducted to evaluate the effects of decision variables on the performances of the GT-MHR and combined cycles. The performances of these cycles are then optimized from the viewpoints of first law, second law and exergoeconomics. It is found that, combining the GT-MHR with ammonia–water cycle not only enhances the first and second law efficiencies of the GT-MHR, but also it improves the cycle performance from the exergoeconomic perspective. The results show that, when the optimization is based on the exergoeconomics, the unit cost of products is reduced by 5.4% in combining the two mentioned cycles. This is achieved with a just about 1% increase in total investment cost rate since the helium mass flow in the combined cycle is lower than that in the GT-MHR alone.

14/02481 Application of probabilistic modelling to the lifetime management of nuclear boilers in the creep regime: Part 2

Bradford, R. A. W. and Holt, P. J. *International Journal of Pressure Vessels and Piping*, 2013, 111–112, 232–245.

Monte Carlo probabilistic simulation has been applied to a large population of nominally identical components in an advanced gas-cooled reactor boiler operating in the creep regime. Some of the components have a history of partial steam flow restrictions which can cause an elevation of their operating temperature, potentially raising the rate of creep life usage. Metal losses due to steam-side and gas-side oxidation and chemical cleaning operations can also exacerbate the rate of creep life usage. The R5 procedure has been used within a probabilistic programme to calculate the expected frequency of both creep rupture and creep-fatigue crack initiation. The probabilistic approach is shown to provide a better quantitative guide to the commercial threat than traditional deterministic methodologies based on bounding data. In particular, probabilistic assessments identify the parameters which most significantly influence plant life.

14/02482 Axisymmetric whole pin life modelling of advanced gas-cooled reactor nuclear fuel

Mella, R. and Wenman, M. R. *Journal of Nuclear Materials*, 2013, 437, (1–3), 154–165.

Thermo-mechanical contributions to pellet–clad interaction (PCI) in advanced gas-cooled reactors (AGRs) are modelled in the ABAQUS finite element (FE) code. User supplied sub-routines permit the modelling of the non-linear behaviour of AGR fuel through life. Through utilization of ABAQUS's well-developed pre- and post-processing ability, the behaviour of the axially constrained steel clad fuel was modelled. The two-dimensional axisymmetric model includes thermo-mechanical behaviour of the fuel with time and condition dependent material properties. Pellet cladding gap dynamics and thermal behaviour are also modelled. The model treats heat up as a fully coupled temperature-displacement study. Dwell time and direct power cycling was applied to model the impact of online refuelling, a key feature of the AGR. The model includes the visco-plastic behaviour of the fuel under the stress and irradiation conditions within an AGR core and a non-linear heat transfer model. A multi-scale fission gas release model is applied to compute pin pressure; this model is coupled to the PCI gap model through an explicit fission gas inventory code. Whole pin, whole life, models are able to show the impact of the fuel on all segments of cladding including weld end caps and cladding pellet locking mechanisms (unique to AGR fuel). The development of this model in a commercial finite element package shows that the development of a potentially verified and future-proof fuel performance code can be created and used.

14/02483 Corrosion behavior of Si-enriched steels for nuclear applications in liquid lead–bismuth

Kurata, Y. *Journal of Nuclear Materials*, 2013, 437, (1–3), 401–408.

The corrosion behaviour of Si-enriched steels in liquid lead–bismuth was studied in order to develop accelerator-driven systems for transmutation of long-lived radioactive wastes and lead–bismuth cooled fast reactors. The corrosion tests of 316SS, Si-enriched 316SS, Mod.9Cr–1Mo steel (T91) and Si-enriched T91 were conducted at $550\,^{\circ}\mathrm{C}$ in liquid lead–bismuth at the two controlled oxygen levels. Both the additions of 2.5 wt% Si to 316SS and 1.5 wt% Si to T91 had the effect of reducing the thickness of oxide layer in liquid lead–bismuth at the high oxygen concentration (2.5×10^{-5} wt%). Although the Si addition to 316SS reduced the depth of ferritization caused by Ni dissolution in liquid lead–bismuth at the low oxygen concentration (4.4×10^{-8} wt%), it could not suppress the ferritization and the penetration of Pb and Bi completely. The Si addition to T91 did not have the effect of preventing the penetration of Pb and Bi in the liquid lead–bismuth at the low oxygen concentration. The oxide scales formed on both Si-enriched steels did not have sufficient corrosion resistance under the low oxygen condition.

Economics, policy, supplies, forecasts

14/02484 Cost estimates for nuclear power in the UK

Harris, G. *et al. Energy Policy*, 2013, 62, 431–442.

The present UK government's support for nuclear power has in part been informed by cost estimates suggesting that electricity from new nuclear power stations will be competitive with alternative low-carbon generation options. The evidence and analysis presented in this paper suggests that the capital cost estimates for nuclear power that are being used to inform these projections rely on costs escalating over the pre-construction and construction phase of the new build programme at a level significantly below those that have been experienced by past US and European programmes. This paper applies observed construction time and cost escalation rates to the published estimates of capital costs for a new nuclear plant in the UK and calculates the potential impact on levelized cost per unit of electricity produced. The results suggest that levelized cost may turn out to be significantly higher than expected. This, in turn, has important implications for policy, both in general terms of the potential costs to consumers and more specifically for negotiations around the level of policy support and contractual arrangements offered to individual projects through the proposed contract for difference strike price.

14/02485 Demarketing fear: bring the nuclear issue back to rational discourse

Han, C. C. *Energy Policy*, 2014, 64, 183–192.

This paper attempts to explore the strategies for breaking the deadlock between the demand for resolving climate crisis and the resistance to deploying nuclear power. Since our present renewable technology is not advanced enough to replace fossil fuel power plants, nuclear power becomes the only available means that can buy us more time to explore better energy sources for coping with the dilemma of climate change and energy security. Therefore, this paper proposes an elaborated fear appeal framework that may shed light on the intervention points for mitigating fear. By examining the influence of fear appeal on the nuclear issue, three strategies for demarketing the nuclear fear of the public are recommended. The paper concludes that only when energy policy makers and the nuclear industry recognize the significance of minimizing fear and begin to work on removing the sources of fear, can we then expect to bring the nuclear issue back to rational discourse.

14/02486 Factors influencing the public intention to use renewable energy technologies in South Korea: effects of the Fukushima nuclear accident

Park, E. and Ohm, J. Y. *Energy Policy*, 2014, 65, 198–211.

The Fukushima nuclear accident has influenced public attitudes toward energy sources and technologies, including not only nuclear energy, but also to others. Therefore, it is worth investigating how the accident influenced public perceptions of renewable energy and its technologies between the time before the accident and after the accident. This study aims to explore the effects of the Fukushima accident on the public perceptions of renewable energy technologies in South Korea, the closest nation to Japan. This study found that there were notable differences of public perceptions, including public attitudes, perceived benefits, trust, intention to use, knowledge and risks between before and after the earthquake. In addition, the perceived cost of renewable energy technologies was the primary determinant of the intention to use the technologies before the accident, whereas public attitudes toward the technologies became the main antecedents of the intention after the accident. After the accident, the authors found that there is a multi-dimensional matrix of perceived trust-benefits (with risks)-attitude-intention to use, in explaining the public acceptance of renewable energy technologies. Moreover, the authors found significant roles of the perceived trust, benefits and risks in the research model. Based on the empirical findings, both implications and suggestions are presented.

14/02487 Hedging electricity price volatility using nuclear power

Mari, C. *Applied Energy*, 2014, 113, 615–621.

The analysis presented in this paper aims to put provide evidence of the role of nuclear power as a hedging asset against the volatility of electricity prices. The unpredictability of natural gas and coal market prices as well as the uncertainty in environmental policies may affect power generating costs, thus enhancing volatility in electricity market prices. The nuclear option, allowing the generation of electricity without carbon emissions, offers the possibility to reduce the volatility of electricity prices through optimal diversification of power-generating technologies. This paper provides a methodological scheme to plan well-diversified 'portfolios' of generating capacity that minimize the electricity price risk induced by random movements of fossil fuels market prices and by unpredictable fluctuations of carbon credits prices. The analysis is developed within a stochastic environment in which the dynamics of fuel prices as well as the dynamics of carbon credits prices is assumed to evolve in time according to well defined Brownian processes. Starting from market data and using Monte Carlo techniques to simulate generating cost values, the hedging argument is developed by selecting optimal portfolio of power generating technologies using a mean–variance approach.

14/02488 Nuclear power in Australia: a comparative analysis of public opinion regarding climate change and the Fukushima disaster

Bird, D. K. *et al. Energy Policy*, 2014, 65, 644–653.

A nation-wide survey was conducted in 2010 to investigate the Australian public's attitudes to nuclear power in relation to climate change and in comparison to other energy alternatives. The survey showed a majority of respondents (42%) willing to accept nuclear power if it would help tackle climate change. Following the disaster at the Fukushima Daiichi nuclear power complex in Japan, an event triggered by the 11 March 2011 Tohoku earthquake and tsunami, it was expected that support for nuclear power in Australia would change. In light of this, a follow-up survey was conducted in 2012. Indeed, the post-Fukushima results show a majority of respondents (40%) were not willing to accept nuclear power as an option to help tackle climate change, despite the fact that most Australians still believed nuclear power to offer a cleaner, more efficient option than coal, which currently dominates the domestic production of energy. Expanding the use of renewable energy sources (71%) remains the most popular option, followed by energy-efficient technologies (58%) and behavioural change (54%). Opposition to nuclear power will continue to be an obstacle against its future development even when posed as a viable solution to climate change.

14/02489 Nuclear-renewable hybrid energy systems: opportunities, interconnections, and needs

Ruth, M. F. *et al. Energy Conversion and Management*, 2014, 78, 684–694.

As the USA's energy system evolves, the amount of electricity from variable-generation sources is likely to increase, which could result in additional periods when electricity demand is lower than available production. Thus, purveyors of technologies that traditionally have provided base-load electricity – such as nuclear power plants – can explore new operating procedures to deal with the associated market signals. Concurrently, innovations in nuclear reactor design coupled with sophisticated control systems now allow for more complex apportionment of heat within an integrated system such as one linked to energy-intensive chemical processes. This paper explores one opportunity: nuclear-renewable hybrid energy systems. These are defined as integrated facilities comprised of nuclear reactors, renewable energy generation and industrial processes that can simultaneously address the need for grid flexibility, greenhouse gas emissions reductions, and optimal use of investment capital. Six aspects of interaction (interconnections) between elements of nuclear-renewable hybrid energy systems are identified: thermal, electrical, chemical, hydrogen, mechanical and information. Additionally, system-level aspects affect selection, design and operation of this hybrid system type. Throughout the paper, gaps and research needs are identified to promote further exploration of the topic.

14/02490 Uranium and nuclear power: the role of exploration information in framing public policy

Mason, C. F. *Resource and Energy Economics*, 2014, 36, (1), 49–63.

As the importance of addressing climate change increases the future global role for nuclear power, the demand for uranium will increase. Expanded uranium reserves will be needed to meet this increased demand, highlighting the importance of future exploratory efforts. To shed light on the social desirability of future exploration levels, the author analyses a past expansionary period in the US uranium industry. It was found that exploration levels were smaller than socially efficient during this period, resulting from a deviation between the private and social values of information. Looking forward, public policies can encourage optimal exploration levels by addressing this deviation.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

14/02491 A mixed-integer nonlinear programming approach to the optimal design of heat network in a polygeneration energy system

Zhang, J. *et al. Applied Energy*, 2014, 114, 146–154.

A large number of heat flows at various temperature and pressure levels exist in a polygeneration plant which co-produces electricity and chemical products. Integration of these external heat flows in a heat recovery steam generator (HRSG) has great potential to further enhance energy efficiency of such a plant; however, it is a challenging problem arising from the large design space of heat exchanger network. In this paper, a mixed-integer non-linear programming model is developed for the design optimization of a HRSG with consideration of all alternative matches between the HRSG and external heat flows. This model is applied to four polygeneration cases with different HRSG types, and results indicate that the optimized heat network mainly depends on the HRSG type and the model specification.

14/02492 A power and cooling cogeneration system using mid/low-temperature heat source

Sun, L. *et al. Applied Energy*, 2013, 112, 886–897.

An ammonia–water based system for power and cooling cogeneration using mid/low-temperature heat source is proposed and investigated in this study. The proposed system consists of a Rankine cycle and an absorption refrigeration cycle. The high-temperature portion of waste heat is used for power generation, whereas the low-temperature part is used for refrigeration. In addition, the exhaust heat of the power subsystem is recovered by the refrigeration subsystem. Simulation results show that the equivalent heat-to-power and exergy efficiencies of the proposed cogeneration system can reach 18.6% and 42.0%, respectively. Compared with separate power and refrigeration systems, the proposed system consumes 17.1% less heat with the same output. The effect of turbine exhaust vapour temperature on system performance is investigated. An experimental rig of an absorption refrigeration system with a cooling capacity of 15 kW was built and tested. The proposed system was found to be capable of utilizing mid/low-temperature heat source more efficiently.

14/02493 Advanced exergoeconomic analysis of an electricity-generating facility that operates with natural gas

Açikkalp, E. *et al. Energy Conversion and Management*, 2014, 78, 452–460.

This paper presents an advanced exergy analysis of an electricity generation facility in the Eskisehir industry estate zone in Turkey. The total electricity generation rate is approximately 55 MW. The exergy efficiency of the system is 0.402 and the total exergy destruction rate of the system is 78.242 MW. The unit exergy cost of electrical power that is generated by the system is $25.660/GJ, and the total exergoeconomic factor of the system is 0.247. Advanced exergetic and exergoeconomic analyses were applied to the considered system. The advanced exergoeconomic analysis shows that the combustion chamber, the high-pressure steam turbine and the condenser have great economic improvement potential because of their high exergy destruction cost rates. Similarly, the heat recovery steam generator and the condenser have significant potential because of their investment costs. In addition, suggestions to improve the system economical parameters are provided. Finally, it can be concluded that relations between the components are strong.

14/02494 Allocating electricity production from a hybrid fossil-renewable power plant among its multi primary resources

Beretta, G. P. *et al. Energy*, 2013, 60, 344–360.

The interest in hybrid power production facilities, based on the integration of renewable resources and conventional fossil fuels, is rapidly rising. The question of what fraction of the electricity produced in such facilities is to be considered as produced from the renewable resources is still being debated. This study shows that the conventional fossil-centred-solar-share method and the exergy-based method lead to unfair allocations that may result in unfair access to subsidies granted to renewable electricity. A more balanced single-resource-separate-production-reference (SRSPR) allocation method is proposed based on prescribed reference partial primary energy factors chosen by some authority to represent reference efficiencies of non-hybrid power production from the same renewable and fossil resources used by the hybrid facility. The authors then show that as hybridization gains higher fractions of the local energy market, the SRSPR method may still result in somewhat unfair allocations leading to local market distortions. To overcome this drawback, a more consistent self-tuned-average-local-productions-reference allocation method was formulated, where the electricity allocation fractions are based on the average partial primary energy factors of the actual energy portfolio of the local area that includes the hybrid plant itself. Results are illustrated with reference to a solar-integrated combined cycle facility.

14/02495 Comparative assessment of several creep damage models for use in life prediction

Rouse, J. P. *et al. International Journal of Pressure Vessels and Piping*, 2013, 108–109, 81–87.

The accurate prediction of creep life is of great importance for the structural integrity of high temperature components, such as those used in power generation plant, if safe, efficient and economically responsible operation is to be achieved. Continuum damage mechanics can be used in conjunction with finite element analysis to provide a fundamental step in modelling creep failure. Material constants used in these models are often derived from accelerated creep rupture tests, performed using higher stresses or temperatures than would normally be experienced by real components. In this paper, a comparative assessment of extrapolated failure times for several creep damage models has been under taken for uniaxial, notched bar, closed end straight pipe section and idealized pipe bend geometries (note the pipe geometry was typical of that used in power generation plant) using finite element software. Material constants for each model were determined using creep and creep rupture tests performed on P91 materials under a uniaxial condition and using notched bar specimens to obtain the material properties related to the multiaxial stress state. In all cases, a hyperbolic sine function creep law was found to consistently give reduced failure times, compared to power law based models (e.g. Liu–Murakami and Kachanov–Robotnov), when stresses below those used in the creep tests were considered.

14/02496 Design improvements and performance testing of a biomass gasifier based electric power generation system

Raman, P. and Ram, N. K. *Biomass and Bioenergy*, 2013, 56, 555–571.

The objective of this research work is to design and develop a downdraft gasifier-based power generation system of 75 kW_e. A heat exchanger was designed and installed which recycles the waste heat of the hot gas, to improve the efficiency of the system. An improved ash removal system was introduced to minimize the charcoal removal rate from the reactor and to increase the gas production efficiency. A detailed analysis of the mass, energy and elemental balance is presented in the paper. The cold gas efficiency of the system is increased from 75.0% to 88.4%, due to the improvements made in the ash removal method. The specific fuel consumption rate of the system is 1.18 $kg\,kWh^{-1}$. The energy conversion efficiency of the system, from fuel wood to electric power was found to be 18%. Significant increase in calorific value of the producer gas was achieved by supplying hot air for gasification.

14/02497 Effect of cycle coupling-configuration on energy cascade utilization for a new power and cooling cogeneration cycle

Jing, X. and Zheng, D. *Energy Conversion and Management*, 2014, 78, 58–64.

To recover mid-low grade heat, a new power/cooling cogeneration cycle was proposed by combining the Kalina cycle and the double-effect ammonia–water absorption refrigeration (DAAR) cycle, and the equivalent heat-to-power and exergy efficiencies of the cogeneration cycle reached 41.18% and 58.00%, respectively. To determine the effect of cycle coupling-configuration on energy cascade utilization for the new cycle, the cycle coupling-configuration of the Kalina and DAAR cycles were first analysed, after which the cycle coupling-configuration of the new cycle was analysed. Analysis results showed that the cycle coupling-configuration of the new cycle enhanced the energy cascade utilization. Furthermore, the energy efficiency boosting mechanism of the new cycle was elucidated.

14/02498 Energy management in a microgrid with distributed energy resources

Zhang, L. *et al. Energy Conversion and Management*, 2014, 78, 297–305.

A smart grid power system with renewable energy resources and distributed energy storage shows significant improvements in the power system's emissions reduction, reliability, efficiency and security. A microgrid is a small-scale smart grid which can be stand-alone or grid-tied. Multiple microgrids form a network with energy management and operational planning through two-way power flow and communication. To comprehensively evaluate the performance of a microgrid, a performance metric is proposed by giving a weighting factor to electricity price, emissions and service quality. Thus, the performance metric is flexible according to the consumers' preference. With the weighting factors set in this paper, this performance metric is further applied on microgrids operated as stand-alone, grid-tied and networked. Each microgrid consists of a solar panel, a hydrogen fuel cell stack, an electrolyser, a hydrogen storage tank, and a load. For a stand-alone system, the load prediction reduces the daily electricity consumption by about 5.7%, the quantity of H_2 stored fluctuates widely and overall performance indexes increase with the solar panel size. In a grid-tied microgrid, the load prediction has a significant effect on the daily electricity consumption which drops 25% in 4 days, some daytime loads are shifted to the night-time, and the capacity of the hydrogen tank is lower than that in a stand-alone microgrid. In a network with multiple microgrids, the control of the power distribution strongly affects the microgrid's performance. However, the overall performance index instead of any specific index increases with the microgrid's power generated from renewable energy resources.

14/02499 Energy matching analysis of on-site micro-cogeneration for a single-family house with thermal and electrical tracking strategies

Cao, S. *et al. Energy and Buildings*, 2014, 68, 351–363.

This paper conducts matching analysis for micro-cogeneration products with generated electrical power (G_{elec}) range 0.5–2.0 kWe and an electrical-to-thermal ratio (ETTR) range of 0.05–0.80 for a Finnish single-family house. Using the recently defined matching indices and evolved criteria, the matching capabilities are comprehensively assessed from both electrical and thermal heat matching aspects. Furthermore, both of the thermal tracking (with electrical grid feed-in) and electrical tracking (with thermal heat grid feed-in) strategies are considered. The simulation tool is TRNSYS 17. In terms of the averaged matching index under the thermal tracking strategy without battery, the best matching happens with a fuel cell with G_{elec} of 1.5 kWe and ETTR of 0.8, whereas under the condition with battery, the best matching happens with a Stirling engine or internal combustion engine with G_{elec} of 1.0 kWe and ETTR of 0.3. Under the electrical tracking strategy, the best matching happens with a Stirling engine with G_{elec} of 1.0–2.0 kWe and ETTR of 0.25. However, by putting certain preferences on the specific aspects of the matching capability, the best matching might be altered, which can be assessed using a weighted matching index. There is no linear relation between matching and primary energy consumption.

14/02500 Energy-saving effect of a residential polymer electrolyte fuel cell cogeneration system combined with a plug-in hybrid electric vehicle

Wakui, T. *et al. Energy Conversion and Management*, 2014, 77, 40–51.

The energy-saving effect of a residential polymer electrolyte fuel cell cogeneration system (PEFC-CGS) that adopts a daily start–stop operation with no reverse power flow, combined with a plug-in hybrid electric vehicle (PHEV) is analysed by an optimal operational planning model based on mixed-integer linear programming. This combined use aims to increase the electric capacity factor of the PEFC-CGS by charging the PHEV using the PEFC-CGS output late at night, and targets the application in regions where the reverse power flow from residential cogeneration systems to commercial electric power systems is not permitted, such as in Japan. First, the optimal operational planning model that incorporates the daily start–stop operation of the PEFC-CGS is developed. The energy-saving effect of the combined use of the PEFC-CGS and PHEV is then analysed on the basis of observations of the optimal operation patterns for a 0.75-kWe PEFC-CGS, a simulated energy demand with a sampling time of 5 min, and various daily running distances of the PHEV. The results show that the combined use of the PEFC-CGS and PHEV increases the electric capacity factor and hot water supply rate of the PEFC-CGS and saves more energy in comparison with their separate use in which the PEFC-CGS is used but the PHEV is charged only using purchased electric power. Consequently, this feasibility study reveals that the combined use of the PEFC-CGS and PHEV provides the synergistic effect on energy savings in the residential and transport sectors.

14/02501 Enhancement of voltage quality in a passive network supplied by a VSC-HVDC transmission under disturbances

Tang, X. and Lu, D. D.-C. *International Journal of Electrical Power & Energy Systems*, 2014, 54, 45–54.

When a voltage-source converter (VSC)-high-voltage direct-current (HVDC) transmission is connected to a passive network, the receiving AC system is weak and is subject to power quality problems such as voltage sag and swell. Dynamic performance of voltage control would affect the voltage quality in the receiving AC system directly. The direct voltage control (DVC) method is simple but fails to quickly eliminate voltage fluctuation caused by load current change. One solution is to add a feed-forward controller to the DVC. The inverter non-linearities, however, degrade the performance of the feed-forward controller. This paper presents a modified direct voltage control to enhance control dynamics in the receiving AC system by overcoming the effect of inverter non-linearities. In the proposed control scheme, the influence of inverter non-linearities on the performance of the feed-forward controller is first discussed. A compensation method for non-linearities of the inverter is then designed in the *d–q* rotating axis. Moreover, to overcome parameter sensitivity of the feed-forward controller, a feedback loop with a PI controller is implemented. Simulation results using PSCAD/EMTDC showed that the VSC-HVDC system using the proposed control scheme, as compared to that with the conventional control methods, has a better capability to mitigate voltage fluctuation during system disturbances.

14/02502 Fast and accurate solution for the SCUC problem in large-scale power systems using adapted binary programming and enhanced dual neural network

Shafie-khah, M. *et al. Energy Conversion and Management*, 2014, 78, 477–485.

This paper presents a novel hybrid method for solving the security constrained unit commitment (SCUC) problem. The proposed formulation requires much less computation time in comparison with other methods while assuring the accuracy of the results. Furthermore, the framework provided here allows including an accurate description of warmth-dependent start-up costs, valve point effects, multiple fuel costs, forbidden zones of operation and AC load flow bounds. To solve the non-convex problem, an adapted binary programming method and enhanced dual neural network model are utilized as optimization tools, and a procedure for AC power flow modelling is developed for including contingency/security issues, as new contributions to earlier studies. Unlike classical SCUC methods, the proposed method allows to simultaneously solve the unit commitment problem and comply with the network limits. In addition to conventional test systems, a real-world large-scale power system with 493 units has been used to fully validate the effectiveness of the novel hybrid method proposed.

14/02503 Flow of cooling air in an electric generator model – an experimental and numerical study

Moradnia, P. *et al. Applied Energy*, 2014, 114, 644–653.

The need for electric power is continuously increasing. The power output of existing electric generators is forced to its limit, and the new intermittent electric energy sources increase the variations of the operating conditions of the electric generators in the power system. This requires better cooling of the heat that is generated by the electric losses in generators. New experimental and numerical techniques need to be developed and validated, to increase the knowledge of the cooling processes and to improve the accuracy of the design tools. The present work focuses on the flow of air through electric generators, as a necessary and important first step towards future accurate and detailed convective heat transfer analysis. A half-scale model of an electric generator is designed and manufactured specifically for detailed experimental and numerical studies of the flow of cooling air through the machine. The model is slightly simplified compared to the original geometry, to benefit from the use of geometry parameterization, and with numerical mesh quality in mind already at the design of the experimental set-up. Special care is taken to provide optical access for accurate and detailed particle image velocimetry (PIV) measurements inside the machine. The experimental measurements include PIV measurements at the inlet and inside the machine, and total pressure measurements at the outlet of the stator channels. Computational fluid dynamics simulations are performed using two approaches. In one approach the inlet flow rate is specified from the experimental data, as is commonly done in the literature. In the other approach the flow rate is determined from the numerical simulation, independently of the experimental results, yielding predictions differing by 2–7% compared to the experimentally estimated values. The results of both approaches capture the experimental flow details to a high level of accuracy. Mesh sensitivity studies highlight the need of a specific resolution of the baffle edges.

14/02504 Fuel switching in power-plants: modelling and impact on the analysis of energy projects

Varympopiotis, G. *et al. Energy Conversion and Management*, 2014, 77, 650–667.

In electricity markets, where conditions are uncertain, the choice of the best technology and the optimization of production processes may not be sufficient to ensure the optimal investment yield of energy business plans. Providing some aspects of flexibility might enhance markets' financial performance; fuel switching may prove to be an alternative option, offering operational flexibility over time, as well as significant financial benefits. Traditional investment analysis methods are considered marginally useful to analyse this case. Instead, the recent tools of time-dependent investment analysis are more appropriate, since they are not inherently restricted to immediate, irreversible decisions. In the present work, a time-dependent computational model is presented and applied in the case study of the Greek power sector, in order to estimate the potential advantages of the fuel switching concept. Moreover, the optimal timing of switching is derived to ensure increasing yields of an average-capacity power plant. The results of the research indicate significant financial benefits anticipated in most scenarios from applying fuel switching, compared to single-fuelled electricity generation units. Security of fuel supply and enhanced flexibility may also be offered to the power plant since more than one technology and fuels may be engaged.

14/02505 Fuzzy multicriteria selection among cogeneration systems: a real case application

Alcan, P. *et al. Energy and Buildings*, 2013, 67, 624–634.

An increase in population size and energy demands are causing higher energy consumption in Turkey. As a parallel of increasing energy demands, Turkey's carbon emissions are on the rise, per capita energy consumption and per capita carbon emissions are trending upwards. Because of economic and environmental reasons, the cogeneration system is very important for Turkey. In addition to the energy and cost savings, the benefits of a cogeneration system are mainly from lower air pollutants emissions to the atmospheric environment, in particular carbon dioxide and nitrous oxide. The main aim of this article is to identify and discuss some of the important and critical decision criteria to select the best cogeneration system providing the most satisfaction with the help of the fuzzy analytic hierarchy process (AHP) and fuzzy technique for order preference by similarity to ideal solution (TOPSIS) methods for a prominent hotel in Istanbul. The decision process is analysed with a real case application for one of the biggest hotel's needs in Istanbul. Also, Turkey wants to select the most appropriate cogeneration system to meet the hotel's electricity and heat requirements. The results of the fuzzy AHP are compared with the results of fuzzy TOPSIS.

14/02506 Higher-capacity lithium ion battery chemistries for improved residential energy storage with micro-cogeneration

Darcovich, K. *et al. Applied Energy*, 2013, 111, 853–861.

Combined heat and power on a residential scale, also known as micro-cogeneration, is currently gaining traction as an energy savings practice. The configuration of micro-cogeneration systems is highly variable, as local climate, energy supply, energy market and the feasibility of including renewable type components such as wind turbines or photovoltaic panels are all factors. Large-scale lithium ion batteries for electrical storage in this context can provide cost savings, operational flexibility, and reduced stress on the distribution grid as well as a degree of contingency for installations relying upon unsteady renewables. Concurrently, significant advances in component materials used to make lithium ion cells offer performance improvements in terms of power output, energy capacity, robustness and longevity, thereby enhancing their prospective utility in residential micro-cogeneration installations. The present study evaluates annual residential energy use for a typical Canadian home connected to the electrical grid, equipped with a micro-cogeneration system consisting of a Stirling engine for supplying heat and power, coupled with a nominal 2 kW/6 kW h lithium ion battery. Two novel battery cathode chemistries, one a new Li–NCA material, the other a high voltage Ni-doped lithium manganate, are compared in the residential micro-cogeneration context with a system equipped with the presently conventional $LiMn_2O_4$ spinel-type battery.

14/02507 Modeling, simulation and experimental set-up of a renewable hydrogen-based domestic microgrid

Valverde, L. *et al. International Journal of Hydrogen Energy*, 2013, 38, (27), 11672–11684.

This paper considers domestic microgrid modelling and simulation covering some aspects not fully addressed in the existing literature. Specifically, most of the reviewed generic models are suitable for long-term simulations but only considering steady-state and nominal operating conditions, which overestimate the energy outputs, hydrogen production and system performance. More specific models are capable of capturing the accurate dynamics of each individual piece of equipment. However, their complexity leads to a high computational burden making it difficult to implement an overall system-scope model including all the interconnected equipment for long-term calculations. This paper seeks to rectify the problem presented by the detected lack of medium-complexity dynamic models of renewable systems with intermediate storage, proposing a domestic microgrid solution composed of photovoltaics, metal hydride hydrogen-based storage with an electrolyser, polymeric electrolyte fuel cell and interconnections with neighbour grids and electric vehicles. This model is validated with experimental data gathered from a pilot microgrid plant designed, built and operated by the authors, and matching simulated data closely.

14/02508 Multi-objective optimized management of electrical energy storage systems in an islanded network with renewable energy sources under different design scenarios

Ippolito, M. G. *et al. Energy*, 2014, 64, 648–662.

This paper addresses the definition of some strategies for the design and the optimized management of electrical energy storage (EES) systems, for an existing islanded distribution network supplying the Italian island of Pantelleria in the Mediterranean Sea. In the paper the authors have drawn conclusions through the application of an efficient multiobjective optimization algorithm, NSGA-II, minimizing the energy losses in the grid, the total electricity generation cost and the greenhouse gas emissions. The results obtained for different installation scenarios of the EES are presented and discussed, putting into evidence the technical, environmental and economic benefits of using EES as well as the technical issues connected to their installation into an existing distribution network. The paper describes the second part of a feasibility study about the transition from a 'fuel-based' traditional centralized electrical system to an active and smart 'renewables-based' electrical distribution system.

14/02509 Peak and off-peak operations of the air separation unit in oxy-coal combustion power generation systems

Hu, Y. *et al. Applied Energy*, 2013, 112, 747–754.

Introducing CO_2 capture and storage (CCS) into the power systems requires the re-investigation of the load balance for the electrical grid. For the oxy-coal combustion capture technology, the energy use of air separation units (ASUs) can be shifted between the peak load and off-peak load periods, which may bring more benefits. In this paper, peak and off-peak (POP) operations for the ASU with liquid oxygen storage were studied based on a 530 MW coal-fired power system. According to the simulation results, the oxy-coal combustion power system running POP is technically feasible that it can provide a base load of 496 MW during the off-peak period and a peak load of 613 MW during the peak period. And the equivalent efficiency of the power system running POP is only 0.3% lower than the one not running POP. Moreover, according to the economic assessments based on the net present value, it is also economically feasible that the payback time of the investment of the oxy-coal combustion power system running POP is about 13 years under the assumptions of 10% discount rate and 2.5% cost escalation rate. In addition, the effects of the difference of on-grid electricity prices, daily peak period, investment for POP operations, and ASU energy consumption were also analysed, concerning the net present value.

14/02510 Predictive direct power control for photovoltaic grid connected system: an approach based on multilevel converters

Barra, K. and Rahem, D. *Energy Conversion and Management*, 2014, 78, 825–834.

This paper presents an improved predictive power control for a photovoltaic conversion chain connected to a grid based on finite states space model of the converter. The proposed control algorithm selects the switching state of the inverter that minimizes the error between active and reactive power predictions to their computed values for all different voltage vectors. The optimal voltage vector that minimizes a cost function is then applied to the output of the power converter. Once the proposed predictive strategy is validated, a multilevel converter is then used to improve and highlight the obtained results. The proposed predictive control strategy uses only one sample time prediction and it is very intuitive since it is very simple and provides best performances compared to other modulation techniques.

14/02511 Steady-state creep peak rupture stresses in 90° power plant pipe bends with manufacture induced cross-section dimension variations

Rouse, J. P. *et al. International Journal of Pressure Vessels and Piping*, 2013, 105–106, 1–11.

Pipe bends represent geometric discontinuities in the steam pipe systems of power plants, therefore understanding the behaviour of these potential locations of weakness is of great industrial importance for component inspection, design and analysis. Due to the high operating temperatures encountered, the failure mechanism of creep is a justified concern. Furthermore, while the geometry of pipe bends appears to be simplistic, the manufacturing process employed results in variations to the critical dimensions of the pipe bends. It is these variations in geometry that can cause potentially significant differences in peak steady-state rupture stress magnitude (approximately 48% in some of the cases considered in the present work). Through analysis of industrial data, several novel non-dimensional parameters have been established, allowing for (with suitable constraint equations depending on the type of bends analysed) the approximation of the complexity of pipe bend geometry in only a few dimension factors. Using these factors, systematic finite element analysis studies may be completed with these non-dimensional parameters taking account of a range of geometry variation. Using this philosophy, the stress states and failure lives of pipe bends of the same type (i.e. hot reheat or main steam) with similar, but not identical, dimensions may be estimated and compared using approximations of the peak rupture stress function. By way of example, this procedure is applied to main steam and hot reheat type 90° pipe bend geometries. The accuracy of interpolation for the stress function is also analysed, along with comments on failure locations and possible future improvements.

14/02512 Theoretical analysis of performance of a micro gas turbine co/trigeneration system for residential buildings in a tropical region

Basrawi, F. *et al. Energy and Buildings*, 2013, 67, 108–117.

This study shows performance of micro gas turbine (MGT)-based cogeneration system (CGS) and trigeneration system (TGS) in residential buildings located in a tropical climate. Energy, economic and environmental performance of MGT-CGS and MGT-TGS were studied. MGT-CGS consists of an MGT and an exhaust heat exchanger (EHE), whereas MGT-TGS consists of an MGT, an EHE, an absorption heat pump and heat storage. Heat storage was essential for storing heat generated during daytime to be utilized during the night when heat demand was higher. MGT-TGS was a better configuration compared to MGT-CGS because it can utilize more exhaust heat and had an energy recovery utilized efficiency ($\eta_{ER,utilized}$) of 0.37 and 0.80 during the day and night, respectively. Furthermore, the payback period for the MGT-TGS was also shorter than MGT-CGS, 13.8 years under highly subsidized electricity tariff. The MGT-TGS also had a higher fuel energy saving index (FESI) when compared to a gas turbine, but had a lower FESI when compared to a combined cycle gas turbine. MGT-CGS and MGT-TGS can also reduce pollutants especially NO_x emissions compared to conventional systems.

14/02513 Theoretical and experimental analyses of a single phase permanent magnet generator (PMG) with multiple cores having axial and radial directed fluxes

Kurt, E. *et al. Energy Conversion and Management*, 2014, 77, 163–172.

A new single-phase generator has been designed and preliminary experimental results have been reported. The effects of two types of alternator cores have been explored. The proposed generator has one stator and two rotors with rare-earth-element-made permanent magnets (PMs). The physical and electromagnetic features of this PM generator are presented. The electromagnetic analyses are realized by the finite element method. The proposed machine has a combined type of flux-directing mechanism, namely with axial and radial directions. The flux orientations are provided by 12 cores at the double-sided stator. The design has two rotors with a total of 24 permanent magnets which are positioned at different radial distances. It has been found that this design reduces the cogging torque values compared to the simple axial flux machine with two rotors having cylindrical cores. Thus a new cogging torque reduction technique is also proposed beside the new design. The electromagnetic simulations have been realized at different rotor speeds. The analyses also include the waveforms of currents, voltages, magnetic fluxes and cogging torque calculations. The maintenance and control of the machine is easier in operation, since the output power increases smoothly and become nearly constant up to the rotor speeds 1000 rpm. Preliminary results indicate that peak-to-peak voltage $U_p = 34$ V is generated at the rotor speed $\omega = 200$ rpm and it increases linearly with ω. The rated speed is expected to be 1000 rpm and 95% of efficiency is measured in the preliminary tests.

14/02514 Transmission grid extensions during the build-up of a fully renewable pan-European electricity supply

Becker, S. *et al. Energy*, 2014, 64, 404–418.

Spatio-temporal generation patterns for wind and solar photovoltaic power in Europe are used to investigate the future rise in transmission needs with an increasing penetration of the variable renewable energy sources (VRES) on the pan-European electricity system. VRES growth predictions according to the national renewable energy action plans of European Union member states are used and extrapolated logistically up to a fully VRES-supplied power system. The authors found that keeping today's international net transfer capacities (NTCs) fixed for the next 40 years reduces the final need for back-up energy by 13% when compared to the situation with no NTCs. An overall doubling of today's NTCs will lead to a 26% reduction, and an overall quadrupling to a 33% reduction. The remaining need for back-up energy is due to correlations in the generation patterns, and cannot be further reduced by transmission. The main investments in transmission lines are due during the ramp-up of VRES from 15% (as planned for 2020) to 80%. Additionally, the results show how the optimal mix between wind and solar energy shifts from about 70% to 80% wind share as the transmission grid is enhanced. Finally, the authors exemplify how reinforced transmission affects the import and export opportunities of single countries during the VRES ramp-up.

14/02515 Virtual synchronous generators: a survey and new perspectives

Bevrani, H. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 244–254.

In comparison of the conventional bulk power plants, in which the synchronous machines dominate, the distributed generator (DG) units have either very small or no rotating mass and damping property. With growing the penetration level of DGs, the impact of low inertia and damping effect on the grid stability and dynamic performance increases. A solution towards stability improvement of such a grid is to provide virtual inertia by virtual synchronous generators (VSGs) that can be established by using short-term energy storage together with a power inverter and a proper control mechanism. The present paper reviews the fundamentals and main concept of VSGs, and their role to support the power grid control. Then, a VSG-based frequency control scheme is addressed, and the paper is focused on the poetical role of VSGs in the grid frequency regulation task. The most important VSG topologies with a survey on the recent works/achievements are presented. Finally, the relevant key issues, main technical challenges, further research needs and new perspectives are emphasized.

Economics, policy, supplies, forecasts

14/02517 A review of electricity product differentiation

Woo, C. K. *et al. Applied Energy*, 2014, 114, 262–272.

This review is motivated by the recognition that an adequate and reliable electricity supply is a critical element in economic growth. From a customer's perspective, electricity has several distinct attributes: quality, reliability, time of use, consumption (kW h) volume, maximum demand (kW) and environmental impact. A differentiated product can be formed by packaging its non-price attributes at a commensurate price. The review weaves the academic literature with examples from the real world to address two substantive questions. First, is product differentiation a meaningful concept for electricity? Second, can product differentiation improve grid operations and planning, thereby lowering the cost of delivering electricity services? Based on this analysis and comprehensive review of the extant literature, the answer is 'yes' to both questions. It was concluded that applying product differentiation to electricity can greatly induce end-users to more effectively and efficiently satisfy their demands on the system, and to do so in an environmentally friendly way.

14/02518 A spatial–temporal model for grid impact analysis of plug-in electric vehicles

Mu, Y. *et al. Applied Energy*, 2014, 114, 456–465.

A spatial–temporal model (STM) was developed to evaluate the impact of large scale deployment of plug-in electric vehicles (EVs) on urban distribution networks. The STM runs based on the integration of power system analysis and transportation analysis. Origin–destination (OD) analysis from intelligent transportation research was used to model the EV mobility. Based on the EV technical and market information provided by the European Union's MERGE project and the output of OD analysis, a Monte Carlo simulation method was developed within the STM to obtain the EV charging load of each load busbar over time. The STM aims to facilitate power system evaluation and planning, and is able to provide both average values and probabilities of nodal bus voltages and branch loadings. The STM is able to identify the critical network components that will require to be upgraded. A high customer density urban network from the UK's generic distribution system combined with geographic information was used as a test system. Two EV charging strategies, 'dumb' charging and 'smart' charging, were simulated and compared under different EV penetration levels (0%, 25% and 50%) to verify the effectiveness of STM.

14/02519 An efficiency oriented model of electricity market in transition period

Yang, S. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 221–225.

Generation efficiency is a key factor to save energy and reduce emissions. Many countries have resorted to the market liberalization for higher efficiency. The reformers usually expect the price could guide the efficiency through the competition between the generators. But the market will not get matured enough in a short time, especially in developing countries. In this efficiency oriented model, the security constraint economic dispatch is adopted to achieve the physical efficiency, and virtual generation right is proposed as the coordinated financial tool to adjust the performance of the generators to be aligned with the efficiency. The simulation demonstrates a typical case with modified 39-bus New England system. The result confirms the feasibility of the model.

14/02520 Assessment of energy supply and continuity of service in distribution network with renewable distributed generation

Abdullah, M. A. *et al. Applied Energy*, 2014, 113, 1015–1026.

Continuity of electricity supply with renewable distributed generation (DG) is a topical issue for distribution system planning and operation, especially due to the stochastic nature of power generation and time-varying load demand. The conventional adequacy and reliability analysis methods related to bulk generation systems cannot be applied directly for the evaluation of adequacy criteria such as 'energy supply' and 'continuity of service' for distribution networks embedded with renewable DG. In this paper, new indices highlighting 'available supply capacity' and 'continuity of service' are proposed for 'energy supply' and 'continuation of service' evaluation of generation-rich distribution networks, and analytical techniques are developed for their quantification. A probability-based analytical method has been developed using the joint probability of the demand and generation, and probability distributions of the proposed indices have been used to evaluate the network adequacy in energy supply and service continuation. A data-clustering technique has been used to evaluate the joint probability between coincidental demand and renewable generation. Time sequential Monte Carlo simulation has been used to compare the results obtained using the proposed analytical method. A standard distribution network derived from the Roy Billinton test system and a practical radial distribution network have been used to test the proposed method and demonstrate the estimation of the well-being of a system for hosting renewable DG units. It is found that renewable DG systems improve the 'energy supply' and 'continuity of service' in the distribution networks. The results suggest that the consideration of the time varying demand and stochastic renewable generation output has significant impact on the 'energy supply' and 'continuity of service' in the distribution networks.

14/02521 Benefit-based expansion cost allocation for large scale remote renewable power integration into the Australian grid

Hasan, K. N. *et al. Applied Energy*, 2014, 113, 836–847.

Climate change policies in different jurisdictions enhance the integration of large-scale remote renewable power generation into the grid, where the remoteness of the location-constrained generation zone and subsequent high transmission investment appear as a potential barrier. Consequently the justification of investment and equitable cost allocation becomes contentious. This research first presents a state-of-the-art review of policy changes in different jurisdictions in this aspect. Then, transmission connection and usage cost allocation are presented to address these challenges accordingly, highlighting the implementation of semi-shallow connection cost allocation policy. Afterwards, the benefit-based allocation of network usage cost is reimbursed through the Shapley value approach. Finally, the investigation of the net market benefit and cost allocation are presented by simulating four large-scale remote renewable transmission projects to be connected to the Australian Queensland network. This study aims to enhance regulatory policies and associated planning frameworks to be more efficient and justifiable for renewable power integration paradigm.

14/02522 Combined environmental and economic dispatch of smart grids using distributed model predictive control

del Real, A. J. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 65–76.

This paper presents an extended distributed model predictive control (DMPC) framework and its application to a smart grid case study. Specifically, a combined environmental and economic dispatch problem is formulated and solved, which is a non-trivial multi-objective optimization problem given the high number of agents, information exchanges and constraints associated to large-scale smart grids. In this line, the work proposed herein adopts a distributed Lagrange-based model predictive control with reduced computational demand making use of robust mixed-integer quadratic programming solvers. In addition, the model predictive control nature of the framework accounts for renewable resource forecast while physical constraints are included in the formulation. The DMPC is herein extended to calculate market-based on-line energy pricing while minimizing the generation cost and emissions, and to include hard and soft constraints and ramp rate limits. The aforementioned control framework is applied to a smart grid composed of 11 consumer centres, six energy storages, 11 generation systems and 31 transmission lines. Simulation results show reductions of generation costs up to 40% when predictions are included in the formulation. Furthermore, the simulation of forecast errors results in up to 8% generation over-cost. These results show that DMPC can be considered as an alternative versus other heuristic methods, which do not guarantee an optimal solution to the problem.

14/02523 Comprehensive efficiency evaluation model for electrical distribution system considering social and urban factors

Dashti, R. *et al. Energy*, 2013, 60, 53–61.

This paper addresses a comprehensive efficiency evaluation model for electrical distribution system. Concerning the efficiency of different resources including energy, infrastructure and human resources, the overall distribution system efficiency is determined on the basis of relevant efficiency indicators. The employed efficiency indicators comprising loss, utilization factor, power factor, load factor, energy not supplied and human resource productivity express the efficiency of the above-mentioned resources. The proposed model takes into account the effect of certain external factors on the performance of distribution system. It has been shown that how external factors such as governance, social behaviour and urban planning can directly influence the efficiency of the system. The correlation between efficiency indicators and external factors is derived using artificial neural network and a sensitivity analysis is conducted to illuminate the path of efficiency increment through managing the effective external factors. These indices can be used for improvement of the system performance in system planning. An empirical study is addressed here based on a real world distribution network to investigate the performance of the proposed model.

14/02524 Cuckoo search algorithm for economic dispatch

Basu, M. and Chowdhury, A. *Energy*, 2013, 60, 99–108.

This paper presents cuckoo search algorithm for solving both convex and non-convex economic dispatch (ED) problems of fossil fuel fired generators considering transmission losses, multiple fuels, valve-point loading and prohibited operating zones. This paper also presents cuckoo search algorithm for micro grid power dispatch problem. Cuckoo search algorithm is a new meta-heuristic algorithm. It is a nature-based searching technique inspired by the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds of other species. The effectiveness of the proposed algorithm has been verified on different test systems. Compared with the other existing techniques, considering the quality of the solution obtained, the proposed algorithm seems to be a promising alternative approach for solving the ED problems in practical power system and micro grid power dispatch problem.

14/02525 Day-ahead deregulated electricity market price forecasting using neural network input featured by DCT

Anbazhagan, S. and Kumarappan, N. *Energy Conversion and Management*, 2014, 78, 711–719.

In a deregulated market, a number of factors determined the outcome of electricity price and displays a perplexed and maverick fluctuation. Both power producers and consumers need a single compact and robust price forecasting tool in order to maximize their profits and utilities. In order to achieve the helter–skelter kind of electricity price, one-dimensional discrete cosine transforms (DCT) input featured feed-forward neural network (FFNN) is modelled (DCT-FFNN). The proposed FFNN is a single compact and robust architecture (without hybridizing the various hard and soft computing models). It has been predicted that the DCT-FFNN model is close to the state of the art can be achieved with less computation time. The proposed DCT-FFNN approach is compared with 17 other recent approaches to estimate the market clearing prices of mainland Spain. Finally, the accuracy of the price forecasting is also applied to the electricity market of New York in 2010 that shows the effectiveness of the proposed DCT-FFNN approach.

14/02526 Demand side management of industrial electricity consumption: promoting the use of renewable energy through real-time pricing

Finn, P. and Fitzpatrick, C. *Applied Energy*, 2014, 113, 11–21.

As the installed capacity of wind generation in Ireland continues to increase towards an overall goal of 40% of electricity from renewable sources by 2020, it is inevitable that the frequency of wind curtailment occurrences will increase. Using this otherwise discarded energy by strategically increasing demand at times that would otherwise require curtailment has the potential to reduce the installed capacity of wind required to meet the national 2020 target. Considering two industrial electricity consumers, this study analyses the potential for the implementation of price based demand response by an industrial consumer to increase their proportional use of wind generated electricity by shifting their demand towards times of low prices. Results indicate that while curtailing during peak price times has little or no benefit in terms of wind energy consumption, demand shifting towards low price times is likely to increase a consumer's consumption of wind generation by approximately 5.8% for every 10% saved on the consumer's average unit price of electricity.

14/02527 Differential electricity pricing and energy efficiency in South Africa

Kohler, M. *Energy*, 2014, 64, 524–532.

By international standards, the economy of South Africa is extremely energy intensive with only a few countries having higher intensities. South Africa's primary energy use per unit of gross domestic product is among the highest in the world. The high energy and electricity intensity of the economy partly reflects South Africa's resource endowments (in particular the abundance of coal) but is also a function of the historical underpricing of coal and electricity by the authorities. South African mining and industrial electricity efficiency is particularly concerning and considerably lower than the global average. This paper sets out to fill a significant gap in the South African energy literature by highlighting the importance of incorporating electricity demand factors as part of the country's energy policy and electricity planning horizon. The paper focuses its attention on modelling the electricity consumption of South Africa's industrial and mining sectors given these account for the lion's share of electricity demand. A differential electricity pricing policy which targets electricity intensive industrial and mining activities (as practised in China since 2004) is viewed by the author to be a superior policy to blanket electricity price increases administered by authorities in an effort to encourage electricity savings and improve energy efficiency in South Africa.

14/02528 Downstream regulation of CO_2 emissions in California's electricity sector

Bushnell, J. *et al. Energy Policy*, 2014, 64, 313–323.

This paper examines the implications of alternative forms of cap-and-trade regulations on the California electricity market. Specific focus is given to the implementation of a downstream form of regulation known as the first-deliverer policy. Under this policy, importers (i.e. first-deliverers) of electricity into California are responsible for the emissions associated with the power plants from which the power originated, even if those plants are physically located outside of California. It was found that, absent strict non-economic barriers to changing import patterns, such policies are extremely vulnerable to reshuffling of import resources. The net impact implies that the first-deliverer policies will be only marginally more effective than a conventional source-based regulation.

14/02529 Economic viability of energy storage systems based on price arbitrage potential in real-time U.S. electricity markets

Bradbury, K. *et al. Applied Energy*, 2014, 114, 512–519.

Energy storage systems (ESSs) can increase power system stability and efficiency, and facilitate integration of intermittent renewable energy, but deployment of ESSs will remain limited until they achieve an attractive internal rate of return (IRR). Linear optimization is used to find the ESS power and energy capacities that maximize the IRR when used to arbitrage 2008 electricity prices (the highest of the past decade) in seven real-time markets in the USA for 14 different ESS technologies. Any reductions in capital costs needed to achieve an IRR of 10% are solved. Results show that the profit-maximizing size (i.e. hours of energy storage) of an ESS is primarily determined by its technological characteristics (round-trip charge/discharge efficiency and self-discharge) and not market price volatility, which instead increases IRR. Most ESSs examined have an optimal size of 1–4 h of energy storage, although for pumped hydro and compressed air systems this size is 7–8 h. The latter ESSs already achieve IRRs >10%, but could be made even more profitable with minimal cost-reductions by reducing power capacity costs. The opposite holds for flywheels, electrical ESSs (e.g. capacitors) and a number of chemical ESSs (e.g. lead–acid batteries). These could be made more profitable with minimal cost-reductions by reducing energy capacity costs.

14/02530 Electricity cost saving comparison due to tariff change and ice thermal storage (ITS) usage based on a hybrid centrifugal-ITS system for buildings: a university district cooling perspective

Abdullah, M. O. *et al. Energy and Buildings*, 2013, 67, 70–78.

In this paper, a case study of a district cooling system of a university located in Malaysia (01°29′N; 110°20′E) is presented. In general, the university has high peak ambient temperature of around 32–35 °C coupled with high humidity of about 85% during afternoon period. The total electricity charge for the Universiti Malaysia Sarawak Campus is very high amounting to more than $314,911 per month. In this paper, a few district cooling schemes are investigated to provide 'what-if analysis' and in order to minimize the overall electricity charges. Few scenarios designed for the application of centrifugal with and without ice-thermal storage systems (ITS) on the buildings were investigated. It was found that, due to the local tariff status, marginally savings can be achieved in the range of 0.08–3.13% if a new tariff is adopted; and a total of further savings of 1.26–2.43% if ITS is operated. This marginally saving is mainly due to the local tariff conditions and lower local temperature range (ΔT) which are less favourable as compared with those reported in the literature elsewhere.

14/02531 Electricity tariff reform and rebound effect of residential electricity consumption in China

Lin, B. and Liu, X. *Energy*, 2013, 59, 240–247.

China has implemented increasing-block power tariffs. It might be a breakthrough in the country's stagnant residential power tariff reform. Improving energy efficiency is the primary method adopted by the Chinese government for energy conservation in residential sector. However, negative effects brought by energy rebound would weaken the real effect of efficiency improvement. Therefore, this paper focuses on the impact of residential electricity tariff adjustment on rebound effect of residential electricity consumption in China. The authors set up a linear approximation of the almost ideal demand system model to estimate the rebound effect of urban residential electricity consumption. The results show that the rebound effect is approximately 165.22%. This figure manifests the existence of 'backfire effect', indicating that efficiency improvement does not have energy-saving effect in practice. After the implementation of increasing-block electricity tariff policy in China, the rebound is reduced to 132.3%. In addition, the authors also obtain the electricity tariffs at which the rebound effect is less than 1 or even close to zero. In this regard, for Chinese electricity market, electricity tariff reform might be an effective method for mitigating rebound effect.

14/02532 Enhancement of building operations: a successful approach towards national electrical demand management

Al-Mulla, A. *et al. Energy Conversion and Management*, 2013, 76, 781–793.

An approach for managing electrical demand through enhanced building operations in hot climates is evaluated and demonstrated in this paper. The approach focuses on implementing enhanced operations in government buildings, since they are easier to implement and administer. These enhanced operations included early reduction of cooling supply before the end of the occupancy period, improved time-of-day control after occupancy period and reduced lighting. A total of eight government buildings with different construction and system characteristics were selected for implementing these enhanced operations. These buildings have a total air-conditioning area of $4.39 \times 10^5\,m^2$ and a combined peak electrical demand of 29.3 MW. The enhanced operations resulted in demand savings of 8.90 MW during the national peak hour. Temperature build up inside the buildings was monitored and found to be within an acceptable range. Guidelines for national implementation in similar buildings were developed based on the results of this work. Implementation is estimated to reduce demand by 488 MW by the year 2030, which amounts to capital savings of $585 million. These projected values would be important to adopt energy-efficient policies for the country. Additional reductions in energy and fuel consumption are added benefits, which would result in large financial and environmental savings to the country. Moreover, the enhanced building operations would be an important tool to avoid any blackouts by properly reducing the peak electrical demand as well as operating the power plants with a higher thermal efficiency.

14/02533 Estimating the economic value of residential electricity use in the Republic of Korea using contingent valuation

Lim, K.-M. *et al. Energy*, 2014, 64, 601–606.

This study attempts to estimate the economic value of residential electricity use in the Republic of Korea. According to micro-economic theory, the economic benefit of residential electricity consumed is the sum of the actual residential electricity price and the additional willingness to pay (WTP) for the consumption. The authors apply the dichotomous choice contingent valuation method to assess the additional WTP. Moreover, the spike model is applied to dealing with the zero WTP responses. The results show that the mean additional WTP for the residential electricity is estimated to be KRW15.38 (US$0.01) per kWh. Given that the average price of residential electricity is KRW103.40 ($0.10) per kWh at the time of the survey, the economic benefit that ensues from the residential electricity consumption is computed as KRW118.78 ($0.11) per kWh. This information can be beneficially utilized in conducting an economic feasibility study for a new project related to residential electricity supply service.

14/02534 Experimental validation of a real time energy management system for microgrids in islanded mode using a local day-ahead electricity market and MINLP

Marzband, M. *et al. Energy Conversion and Management*, 2013, 76, 314–322.

Energy management systems (EMS) are important supervisory control tools used to optimally operate and schedule microgrids (MG). In this paper, an EMS algorithm based on mixed-integer non-linear programming (MINLP) is presented for MG in islanding mode considering different scenarios. A local energy market (LEM) is also proposed with in this EMS to obtain the cheapest price, maximizing the utilization of distributed energy resources. The proposed energy management is based on LEM and allows scheduling the MG generation with minimum information shared sent by generation units. Load demand management is carried out by demand response concept to improve reliability and efficiency as well as to reduce the total cost of energy (COE). Simulations are performed with real data to test the performance and accuracy of the proposed algorithm. The proposed algorithm is experimentally tested to evaluate processing speed as well as to validate the results obtained from the simulation setup on a real MG test bed. The results of the EMS–MINLP based on LEM are compared with a conventional EMS based on LEM. Simulation and experimental results show the effectiveness of the proposed algorithm which provides a reduction of 15% in COE, in comparison with conventional EMS.

14/02535 Long term forecasting of hourly electricity consumption in local areas in Denmark

Andersen, F. M. *et al. Applied Energy*, 2013, 110, 147–162.

Long-term projections of hourly electricity consumption in local areas are important for planning of the transmission grid. In Denmark, at present the method used for grid planning is based on statistical analysis of the hour of maximum load and for each local area the maximum load is projected to change proportional to changes in the aggregated national electricity consumption. That is, specific local conditions are not considered. Yet, from measurements of local consumption it is known that: consumption profiles differ between local areas, consumption by categories of customers contribute differently to the aggregated consumption profile, the weight of categories of customers differ between local areas. This paper presents a model calculating local consumption as composed of consumption by categories of customers with specific consumption profiles and different weights in local areas. The model describes the entire profile of hourly consumption and is a first step towards differentiated local predictions of electricity consumption. The model is based on metering of aggregated hourly consumption at transformer stations covering selected local areas and on national statistics of hourly consumption by categories of customers. The model is estimated on data for the years 2009–2011 (in total 26,280 hourly observations). To evaluate how the model describes present consumption in local areas, observed and simulated hourly load duration curves for 2011 are compared. Using national projections of annual consumption by categories of customers, the model is used to project hourly consumption profiles for selected local areas and results are compared to projections using the existing methodology.

14/02536 Novel effects of demand side management data on accuracy of electrical energy consumption modeling and long-term forecasting

Ardakani, F. J. and Ardehali, M. M. *Energy Conversion and Management*, 2014, 78, 745–752.

Global implementation of demand-side management (DSM) programmes has had a positive impact on electrical energy consumption (EEC) and the examination of their effects on long-term forecasting is warranted. The objective of this study is to investigate the effects of historical DSM data on accuracy of EEC modelling and long-term forecasting. To achieve this objective, optimal artificial neural network (ANN) models based on improved particle swarm optimization (IPSO) and shuffled frog-leaping (SFL) algorithms are developed for EEC forecasting. For long-term EEC modelling and forecasting for the USA for 2010–2030, two historical data types used in conjunction with the developed models: (i) EEC and (ii) socio-economic indicators, namely, gross domestic product, energy imports, energy exports and population for 1967–2009. Simulation results from IPSO–ANN and SFL–ANN models show that using socio-economic indicators as input data achieves lower mean absolute percentage error (MAPE) for long-term EEC forecasting, as compared with EEC data. Based on IPSO–ANN, it is found that, for the US EEC long-term forecasting, the addition of DSM data to socio-economic indicators data reduces MAPE by 36% and results in the estimated difference of 3592.8 MBOE (5849.9 TW h) in EEC for 2010–2030.

14/02537 Potential gains from trading bad outputs: the case of U.S. electric power plants

Färe, R. *et al. Resource and Energy Economics*, 2014, 36, (1), 99–112.

Jointly with kilowatt-hours (kWh), electric power plants also produce CO_2, NO_x, and SO_2. This study applied an environmental production model based on data envelopment analysis to compare the production of kWh under command-and-control regulation of the undesirable by-product with tradable permit regulation of the by-product. This was carried out for each of the three undesirable outputs and combinations of them. The authors applied the model to a dataset of 80 coal-fired electric power plants from 1995 to 2005. From this they were able to identify the potential gains from trading the most common undesirable outputs produced by coal-fired electric power plants.

14/02538 Review of the energy and economic parameters involved in the effectiveness of grid-connected PV systems installed in multi-storey buildings

Orioli, A. and Di Gangi, A. *Applied Energy*, 2014, 113, 955–969.

The assessment of photovoltaic (PV) energy in an urban context is extremely complex because many factors have to be considered. Moreover, when the purpose is calculating the realistic amount of the electricity demand of a city that can be covered by the PV generation, it is necessary to estimate the number of PV systems whose installation is economically advantageous. Such a topic requires an economic analysis which is affected by the number of energy and economic parameters involved and the values assigned to them to perform calculations. Some parameters are perfectly known and unvarying, like the paid incentives. Adversely, some parameters, like the efficiency degradation of PV panels, can only be supposed. Other parameters require some information that is specifically related to each particular PV system. With the aim of estimating the influence of the manifold energy and economic parameters that characterize how PV penetration develops in urban areas, a specific study was conducted for a city in the south of Italy. A sensitivity analysis was carried out in order to verify parameters have an irrelevant influence and what are the parameters whose definition can be a crucial element of the energy and economic analysis of PV systems because dramatically impact on the results. The presented study represents a valuable help for PV systems designers and energy decision-makers because it permits the evaluation of the impact of the deviations of the main parameters on the profitability of PV systems and the role played by them in the effectiveness of the energy policies implemented to achieve the required shares of electricity demand coverage.

14/02539 Semi-pilot scale production of hydrogen from organic fraction of solid municipal waste and electricity generation from process effluents

Sekoai, P. T. and Kana, E. B. G. *Biomass and Bioenergy*, 2014, 60, 156–163.

The production of hydrogen from organic fraction of solid municipal waste was studied on a semi-pilot scale. The potential of generating electricity using the process effluents was further assessed using a two-chambered microbial fuel cell. A maximum hydrogen fraction of 46.7% and hydrogen yield of 246.93 ml $H_2 g^{-1}$ total volatile solids was obtained at optimum operational setpoints of 7.9, 30.29 °C and 60 h for pH, temperature and hydraulic retention time, respectively. A maximum electrical power density of $0.21\,W\,m^{-2}$ ($0.74\,A\,m^{-2}$) was recorded at 500 Ω and the chemical oxygen demand removal efficiency of 50.1% was achieved from the process. The process economics of energy generation from organic wastes could be significantly improved by integrating a two-stage process of fermentative hydrogen production and electricity generation.

14/02540 Susceptibility of the European electricity sector to climate change

Klein, D. R. *et al. Energy*, 2013, 59, 183–193.

The electricity system is particularly susceptible to climate change due to the close interconnectedness between electricity production, consumption and climate. This study provides a country-based relative analysis of 21 European countries' electricity system susceptibility to climate change. Taking into account 14 quantitative influencing factors, the susceptibility of each country is examined both for the current and projected system with the result being a relative ranked index. Luxembourg and Greece are the most susceptible relatively due in part to their inability to meet their own electricity consumption demand with inland production, and the fact that the majority of their production is from more susceptible sources, primarily combustible fuels. Greece experiences relatively warm mean temperatures, which are expected to increase in the future leading to greater summer electricity consumption, increasing susceptibility. Norway was found to be the least susceptible, relatively, due to its consistent production surplus, which is primarily from hydro (a less susceptible source) and a likely decrease of winter electricity consumption as temperatures rise due to climate change. The findings of this study enable countries to identify the main factors that increase their electricity system susceptibility and proceed with adaptation measures that are the most effective in decreasing susceptibility.

14/02541 Sustainability assessment of electricity generation technologies using weighted multi-criteria decision analysis

Maxim, A. *Energy Policy*, 2014, 65, 284–297.

Solving the issue of environmental degradation due to the expansion of the world's energy demand requires a balanced approach. The aim of this paper is to comprehensively rank a large number of electricity generation technologies based on their compatibility with the sustainable development of the industry. The study is based on a set of 10 sustainability indicators which provide a life cycle analysis of the plants. The technologies are ranked using a weighted sum multi-attribute utility method. The indicator weights were established through a survey of 62 academics from the fields of energy and environmental science. The results show that large hydroelectric projects are the most sustainable technology type, followed by small hydro, onshore wind and solar photovoltaic. The authors argue that political leaders should have a more structured and strategic approach in implementing sustainable energy policies and this type of research can provide arguments to support such decisions.

14/02542 The future of the European electricity system and the impact of fluctuating renewable energy – a scenario analysis

Spiecker, S. and Weber, C. *Energy Policy*, 2014, 65, 185–197.

The on-going transformation of the European energy system comes with new challenges, notably increasing amounts of power generation from intermittent sources such as wind and solar. How current objectives for emission reduction can be reached in the future and what the future power system will look like is, however, not fully clear. In particular, power plant investments in the long run and power plant dispatch in the short run are subject to considerable uncertainty. Therefore, an approach is presented which allows electricity market development to be assessed in the presence of stochastic power feed-in and endogenous investments in power plants and renewable energies. To illustrate the range of possible future developments, five scenarios for the European electricity system up to 2050 are investigated. Both generation investments and dispatch as well as utilization of transmission lines are optimized for these scenarios and additional sensitivity analyses are carried out.

07 STEAM RAISING

Boiler operation/design

14/02543 A droplet model in steam condensation with noncondensable gas

Lan, Z. *et al. International Journal of Thermal Sciences*, 2013, 68, 1–7.

A physical and revised mathematical droplet model with respect to molecular clustering is proposed to describe the state of steam molecules before condensing on the cooled solid surface in steam condensation in the presence of non-condensable gas (NCG). Based on the Dillmann and Meier homogeneous nucleation model, introducing the wall conditions and making some correlations, the mathematical model was used to calculate the size distribution of clusters and describe the effect of the presence of NCG on the distribution of clusters. The heat transfer model considering the effect of interfacial effects was used to calculate the shape and temperature of clusters. The predicted results of Gibbs free energy at different subcooling degrees and different saturated temperatures were given. The model well explains the effect of NCG on condensation heat transfer performance and the predicted results are in agreement with the experimental results reported in the literature. That confirms the validity of the model.

14/02544 An environment friendly and efficient lignite-fired power generation process based on a boiler with an open pulverizing system and the recovery of water from mill-exhaust

Ma, Y. *et al. Energy*, 2013, 59, 105–115.

This paper advances a novel lignite-fired power generation process based on a boiler with an open pulverizing system (OPSB) and the recovery of water from mill-exhaust after the comprehensive analysis of the open pulverizing system used for high-moisture coals and heat/water recovery from boiler exhaust. Then, the thermal calculation method that applies to OPSB is presented based on heat and mass balance analyses of the boiler. Finally, an efficient unit applying the OPSB process is compared with a conventional 600 MW lignite-fired power unit, and the performance of the efficient unit is calculated and discussed in detail. The results show that the efficient unit not only yields a notable increase in the boiler's (2.6%) and the power plant's (1.3%) thermal efficiency but also provides a remarkable advantage in water recovery due to the mass of water vapour concentrated in mill-exhaust. In the efficient unit, the volume fraction of water vapour in mill-exhaust reaches 34%, the water reclaimed from mill-exhaust is so much that a lignite-fired power plant with zero water consumption can be expected, while the pollutant emissions can be reduced in proportion to the increase in boiler thermal efficiency.

14/02545 Calculation of the power loss coefficient of steam turbine as a part of the cogeneration plant

Urošević, D. *et al. Energy*, 2013, 59, 642–651.

A cogeneration plant operates under very variable conditions within a reporting period (usually one year) and this frustrates the achievement of the high standards stipulated by the European Union directive from 2004. Taking into consideration these difficulties, one needs to start with the decomposition of the cogeneration plant in order to determine a virtual part of the plant that can meet the requirements of the Directive on the basis of conducted measurements and calculations. In this way, the plant can be partially qualified as eligible for economic and financial benefits. The focus of this paper is an analysis of the power loss coefficient of steam turbines for the generation of useful heat energy and electricity simultaneously. This applies to all cogeneration plants comprising extraction-condensing steam turbines and combined cycles (gas turbine and steam turbine) when heat is extracted prior to the bottoming cycle. The proposed procedure for calculation of power loss coefficient is easily applicable in industrial practice. The viability of the proposed method is demonstrated in the case of calculations for a 10 MW_e (combined cycle gas turbine) plant.

14/02546 Characterization of the oxide formed in the presence of poly acrylic acid over the steam generator structural materials of nuclear power plants

Joshi, A. C. *et al. Journal of Nuclear Materials*, 2013, 437, (1–3), 139–148.

On-line addition of polymeric dispersants, such as polyacrylic acid (PAA), to the steam generator (SG) results in the formation of a better protective inner oxide layer that reduces subsequent corrosion of structural materials. Its dispersive action inhibits the growth of a secondary oxide layer thereby facilitating their easy removal. This paper discusses the effect of PAA on the nature of oxides formed over the surfaces of SG. In the case of carbon steel, the inner oxide layer (magnetite) formed in the presence of PAA was protective. Electrochemical studies showed a minimum concentration of 350 ppb of PAA was found to be optimum. On the monel surface, in the absence of PAA, nickel ferrite was formed while in the presence of PAA, the oxide formed was a mixture of oxides of copper and nickel. A concentration of 700 ppb of PAA was found to be optimum for monel. In the case of incoloy, the effect of PAA was not discernible except for the size and morphology of the crystallites formed.

14/02547 Control-oriented dynamic model optimization of steam reformer with an improved optimization algorithm

Jiang, J. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11288–11302.

An effective temperature controller for steam reformers is critical to ensure a high performance reforming process in the connection of solid oxide fuel cell. The establishment of a control-oriented dynamic model plays an important role in the development of a control system. In this work, a high-fidelity lumped parameter model for a steam reformer is constructed based on physical and chemical laws. In order to fit simulated data to experimental data, such as flow rate and temperature characteristics, a new identification method based on a breed particle swarm optimization algorithm is introduced for parameter identification. The results show that the identified model can achieve an accurate description of the actual plant and can be used to replace it for the development of a control system.

14/02548 Effect of angle of arch-supplied overfire air on flow, combustion characteristics and NO_x emissions of a down-fired utility boiler

Li, Z. *et al. Energy*, 2013, 59, 377–386.

A new overfire air (OFA) technology was proposed by the authors for a Foster Wheeler down-fired boiler, and a small-scale cold experimental system for a 660-MW_e unit was established. The velocity field distribution was measured in the furnace to study the characteristics of single-phase flow in the furnace at different OFA nozzle angles. The furnace temperature and distributions of the O_2 concentration and NO concentration at different OFA nozzle angles were simulated using Fluent 6.3.26, and the average temperature of the furnace outlet, the O_2 and NO_x concentrations and carbon content in the fly ash were calculated. As the OFA nozzle angle increased, the vertical penetration depth of OFA increased and the horizontal penetration depth of OFA gradually decreased. The carbon content in the fly ash and NO_x concentration initially rose and then fell at the furnace outlet, and they were lowest when the OFA angle was set at 20°. Thus, according to the findings of this study, an optimized OFA angle of 20° was chosen.

14/02549 Exergoeconomic and exergoenvironmental evaluation of the coupling of a gas fired steam power plant with a total site utility system

Manesh, M. H. K. *et al. Energy Conversion and Management*, 2014, 77, 469–483.

The purpose of a steam power plant usually is electrical power generation; however, it can work as dual-purpose plant producing steam and power simultaneously. This paper seeks the optimum integration of a steam power plant as a source and a site utility system as a sink of steam and power. Estimating the cogeneration potential prior to the design of a central utility system for site utility systems is important for setting targets for site fuel demand as well as heat and power production. In this regard, an accurate cogeneration targeting procedure is used for the coupling of a steam power plant and a site utility consisting of a process plant. Exergoeconomic and exergoenvironmental evaluations are performed. In the exergoenvironmental analysis, the environmental impacts obtained by life cycle assessment are apportioned to the exergy streams, identifying the main system components with the highest environmental impacts and possible improvements associated with these components. Moreover, exergoenvironmental variables are calculated, and an exergoenvironmental evaluation is carried out. In addition, the cogeneration targeting method has been applied. A gas-fired steam power plant and a process site utility are considered as a case study, with the integration of steam levels of the steam power plant and the site utility system carried out using the new procedure presented in this paper.

14/02550 Experimental investigation into gas/particle flow in a down-fired 350 MWe supercritical utility boiler at different over-fire air ratios

Liu, C. *et al. Energy*, 2014, 64, 771–778.

Gas/particle two-phase flow experiments at different over-fire air ratios were conducted using a 1 : 20 small-scale model of a down-fired 350 MWe superficial utility boiler designed with multiple injections and multiple staging combustion technology. The mean velocity, fluctuating velocity and particle volume flux were measured using particle dynamics anemometer measurements. None of four conditions of pulverized coal short-circuit occurred. When the over-fire air percentage was 1.9% and after the arch air flow reached the tertiary air, the position of maximum gas flow velocity of the arch secondary air and the maximum particle volume flux in the fuel-rich flow was close to and eroded the furnace hopper side wall. When the over-fire air percentage was increased to 9.6%, the position of maximum gas flow velocity of the arch secondary air and the maximum particle volume flux in the fuel-rich flow started to deviate from the hopper side wall but did not erode the furnace side wall. However, when the over-fire air percentage was 9.6%, the gas velocity of the arch air flow entering the furnace hopper was still high and the arch air flow downstream depth was too deep. Therefore, use of an over-fire air percentage greater than 19.1% was recommended.

14/02551 Impact of pressure losses in small-sized parabolic-trough collectors for direct steam generation

Lobón, D. H. and Valenzuela, L. *Energy*, 2013, 61, 502–512.

Using parabolic-trough solar collectors (PTC) for industrial thermal processes for temperatures of up to 300 °C is not novel, but in recent years there has been an increase of interest in this type of concentrating solar technology. One of the problems that arises when designing PTC solar fields is how to deal with the pressure losses which are critical when producing saturated steam directly in the collectors. Depending on the characteristics of the collector, mainly on the receiver diameter, and on the nominal process conditions defined, a solar field configuration can be feasible or not. This paper presents a sensitivity analysis using a software tool developed to study the thermohydraulic behaviour of PTC systems using water steam as heat transfer fluid. In the case study presented, a small-sized PTC designed for industrial process heat applications is considered, which has a focal length of 0.2 m, an aperture area of 2 m^2, and its receiver pipe has an inner diameter of 15 mm. Varied process conditions are inlet water pressure, temperature and mass flow rate, solar irradiance and incidence angle of solar radiation. Results show that working pressure definition is particularly critical to make feasible or not the direct steam generation in solar collectors.

14/02552 Impact of using biomass boilers on the energy rating and CO_2 emissions of Iberian Peninsula residential buildings

Carpio, M. *et al. Energy and Buildings*, 2013, 66, 732–744.

Adequate energy efficiency in any residential building calls for a number of factors to be taken into account as specified in the energy certification of buildings under European Union Directive 2002/91/EU. In particular, the heating systems are essential to optimize the use of energy, and are both efficient and environmentally sustainable, which generally implies the use of renewable energy sources. This paper examines the impact of using biomass boilers on the energy rating and CO_2 emissions in six cities located in the Iberian Peninsula with different climatic conditions. The study compares the use of fossil fuels (natural gas and gas oil) and a renewable energy source (biomass) in heating and hot water systems in two types of residential building. The results underline the influence of the climate in reducing CO_2 emissions and economic costs, and improving the energy rating. A remarkable decline of up to ≈95% in CO_2 emissions may be achieved with the use of biomass, as compared to fossil fuels, with the economic savings being as much as ≈88%. It is concluded that the use of biomass can significantly improve the energy rating; in the best cases the improvement can reach four classes on a scale of seven levels.

14/02553 Influence of feeding ratio on steam gasification of palm shells in a rotary kiln pilot plant. Experimental and numerical investigations

Iovane, P. *et al. Biomass and Bioenergy*, 2013, 56, 423–431.

This paper presents experimental and numerical results on steam gasification of palm shells in a rotary kiln pilot plant. Both the process performance and gas features have been evaluated varying the steam-to-biomass ratio (SBR), defined as the mass of steam divided by the mass of palm shells. First, some experimental tests have been performed. Then, the obtained experimental results have been used to verify the consistency of a numerical model developed with the aid of the commercial code ChemCAD. Numerical results showed that the gas energy content decreases as the SBR increases as well, achieving a maximum value for SBR = 0.6 that produced a gas which volumetric composition N_2 free is $H_2 = 40.4\%$, $CO = 24.1\%$, $CO_2 = 21.7\%$, $CH_4 = 12.2\%$, $C_2H_4 = 1.7\%$ and in correspondence of which the lower heating value is equal to 12 $\mathrm{MJ\,m^{-3}}$ in normal conditions. SBR values higher than 0.6 do not produce a further increase of the gas yield, rather require a greater amount of input energy for heating the steam from the room temperature to the process temperature.

14/02554 Modeling the dynamics of the multiphase fluid in the parabolic-trough solar steam generating systems

Lobón, D. H. *et al. Energy Conversion and Management*, 2014, 78, 393–404.

Direct steam generation in parabolic-trough solar collectors has been under evaluation in recent years for its technical feasibility, process control and cost. Knowledge of the dynamic behaviour of such a system is particularly important as changes in inlet water conditions or in the solar radiation affect the amount of steam generated in the solar field. The process must therefore be controlled to ensure constant quality of produced steam. This work introduces a computational fluid dynamic simulation approach to predict the behaviour of a solar steam generating system, which is located at the Plataforma Solar de Almería, Spain. STAR-CCM+ code has been used to implement an efficient multiphase model capable of simulating the dynamics of the multiphase fluid in parabolic-trough solar collectors. Numerical and experimental data are compared in a wide range of working conditions.

14/02555 Non-equilibrium spontaneous condensation in transonic steam flow

Yousif, A. H. *et al. International Journal of Thermal Sciences*, 2013, 68, 32–41.

Experimental and numerical investigations of non-equilibrium spontaneous condensation in transonic steam flow were carried out in low pressure steam turbine cascade to study the effect of exit pressure variation on two phase flow of saturated vapour and fine water droplet. The conditions at inlet to the test section were varied from a wet equilibrium to a superheated state by changing the cascade exit pressure. Experimentally it was found that the most important influence of rapid condensation on the pressure distribution is occurred on the suction surface, when the exit cascade flow is termed supersonic the heat release causes a pressure rise in the zone of rapid condensation, therefore the term condensation shock for this feature is misleading. In the numerical approach when the flow is regard subsonic the rapid condensation zone occurs downstream the throat and not accompanied by a pressure rise, while in the experimental test for the same case there is no sign of this condensation.

14/02556 Numerical and experimental study of a heat recovery steam generator during start-up procedure

Alobaid, F. *et al. Energy*, 2014, 64, 1057–1070.

The use of renewable energy in electricity and heat supply has gained more importance over time. Accordingly, the efficiency and flexibility of modern thermal power plants should be further improved. To design such a system, it is necessary to generate detailed computer models that can accurately predict the power plant behaviour during fast transients, part loads and start-up procedures. In this work, a dynamic simulation model for a subcritical three-pressure-stage heat recovery steam generator (HRSG) is built, employing the advanced processing simulation software Aspen Plus Dynamics. The simulation results obtained from the HRSG model are validated towards the dynamic measurements during warm start-up procedure. The capability of processing simulation software used to estimate the dynamic behaviour of real HRSG is demonstrated. The HRSG model shows high accuracy at different part loads with a maximum relative error of about 5%. The good agreement suggests that the HRSG model is very reliable and is capable to predict the operational processes.

14/02557 Study of combustion process of biodiesel/gasoil mixture in a domestic heating boiler of 26.7 kW

González-González, J. F. *et al. Biomass and Bioenergy*, 2014, 60, 178–188.

This study is focused on the use of biodiesel in a liquid fuel heating boiler of 26.7 kW. The influence of biodiesel/diesel mixtures, air flow rate, and input pressure on a combustion process for heating purposes was analysed. The study is divided into two parts. The first one deals with the characteristics of biodiesel as a heating fuel and the analysis of its properties and preparation method. The biodiesel was produced from sunflower oil in a pilot plant of 250 L/charge and was characterized according to standard norms. It was found that biodiesel is not acceptable as fuel for internal combustion engines (ester content of 92%). The second one deals with the effect of the operating variables on the combustion parameters in the boiler. The tests were conducted on experimental facilities and the generated emissions were analysed. It was found that increasing the input burner pressure involves a decrease in CO and O_2 and an increase of CO_2 in the fumes, as well as an increase in the combustion process yield. Likewise, a greater air flow rate gives rise to a decrease in the latter parameter. Moreover, CO emissions were slightly higher when biodiesel content was increased in the mixture, and therefore the combustion yield decreased.

08 COMBUSTION

Burners, combustion systems

14/02558 A technical and economic analysis of three large scale biomass combustion plants in the UK

McIlveen-Wright, D. R. *et al. Applied Energy*, 2013, 112, 396–404.

In the past there have been several reasons for not fuelling large-scale power plants with biomass instead of fossil fuels. For example, fossil fuels have higher energy density, their costs had been relatively low until recently, the required (large) amounts of biomass have not been readily available and the cost and environmental impact of road transportation of large quantities of biomass were considerable. However, the impending scarcity of fossil fuels and their increased price, as well as environmental concerns, have led to renewed interest in the use of biomass for power generation. Many power plant operators have been encouraged by subventions to test cofiring of biomass with coal, which has often proved lucrative with little reduction in generation efficiency or significant impact on capital cost, and this, in turn, has increased familiarity with the characteristics of biomass, its handling, diminution, drying, storage and use at power plants and the details of its supply chain. One example of this increase in interest in biomass is the 350 MWe circulating fluidized bed combustion (CFBC) power plant at Port Talbot in Wales. Two other examples are the medium scale biomass power plants, (a) the 44 MWe bubbling fluidized bed system at Steven's Croft, Lockerbie in Scotland and (b) the 30 MWe bubbling fluidized bed combustion (BFBC) at Wilton (Wilton 10) in England. The technical, environmental and economic analysis of such technologies, using the ECLIPSE suite of process simulation software, is the subject of this study. The models are based on publicly-available data from the previously mentioned plants, but are not intended to replicate all aspects of them. System efficiencies for generating electricity and CO_2 emissions are evaluated and compared with a large coal-fired CFBC plant and a typical supercritical coal-fired pulverized fuel power plant. The specific investment and break-even electricity selling price for each system were calculated and compared with the coal-fired plants. The sensitivity of the economics of these large power plants to such factors as fuel cost, load factor and insurance, operational and maintenance costs for two discount cash flow rates was investigated. The specific investment and break-even electricity selling price for the three biomass plants modelled were found to be competitive with the coal-fired plants at low wood costs, even without any subventions. The effect of applying the renewable obligations certificate subvention to the economics of the power plants was also assessed for a wide range of wood fuel costs.

14/02559 Cold-modeling flow characteristics for a 300-MW$_e$ down-fired furnace at different secondary-air distributions

Kuang, M. *et al. International Journal of Thermal Sciences*, 2013, 68, 148–157.

Deflected flow fields and large combustion differences between zones near front and rear walls have been found in down-fired pulverized-coal boilers under symmetric air distribution modes. To eliminate or mitigate the flow-field deflection and achieve relatively symmetric combustion in these boilers, the secondary-air distribution ejected through the front and rear arches was adjusted to construct an asymmetric secondary-air distribution mode. Cold-modelling airflow experiments over a wide range of asymmetric secondary-air distributions (i.e. differences in the ratio of secondary-air mass flow rate between the front and rear arches (R_d) of −16%, −8%, 0%, 5%, 8%, 16% and 32%) were conducted within a small-scale model of a down-fired pulverized-coal 300 MW$_e$ utility boiler. Results revealed that a steady and symmetric flow field could not be achieved simply by adjusting the secondary-air distribution between the front and rear arches. To establish a flow field along with an appropriate airflow reach for more economical operation, an optimal setting of $R_d = 5\%$ was found for the secondary-air distribution between the front and rear arches. Industrial-size measurements revealed that a secondary-air distribution setting of $R_d = 6.3\%$ (i.e. approaching to the cold-modelling optimized result of $R_d = 5\%$) was applicable if applied in the real furnace to deal with asymmetric combustion, low burnout, and high NO_x emissions.

14/02560 Combustion phasing for maximum efficiency for conventional and high efficiency engines

Caton, J. A. *Energy Conversion and Management*, 2014, 77, 564–576.

The importance of the phasing of the combustion event for internal-combustion engines is well known, but quantitative details are sparse. The objective of the current work was to examine the optimum combustion phasing (based on maximum brake mean effective pressure, BMEP) as functions of engine design and operating variables. A thermodynamic, engine cycle simulation was used to complete this assessment. As metrics for the combustion phasing, both the crank angle for 50% fuel mass burned (CA_{50}) and the crank angle for peak pressure (CA_{pp}) are reported as functions of the engine variables. In contrast to common statements in the literature, the optimum CA_{50} and CA_{pp} vary depending on the design and operating variables. Optimum, as used in this paper, refers to the combustion timing that provides the maximum BMEP and brake thermal efficiency (MBT timing). For this work, the variables with the greatest influence on the optimum CA_{50} and CA_{pp} were the heat transfer level, the burn duration and the compression ratio. Other variables such as equivalence ratio, exhaust gas recirculation (EGR) level, engine speed and engine load had a much smaller impact on the optimum CA_{50} and CA_{pp}. For the conventional engine, for the conditions examined, the optimum CA_{50} varied between about 5 and 11° after top dead centre (aTDC), and the optimum CA_{pp} varied between about 9 and 16° aTDC. For a high efficiency engine (high dilution, high compression ratio), the optimum CA_{50} was 2.5° aTDC, and the optimum CA_{pp} was 7.8° aTDC. These more advanced values for the optimum CA_{50} and CA_{pp} for the high efficiency engine were largely due to lower heat losses.

14/02561 Dielectric loss determination of fine residual waste electrical and electronic equipment for understanding of heat development during microwave pyrolysis

Andersson, M. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 142–148.

Waste electrical and electronic equipment (WEEE) contains rare and valuable metals which are important to recycle, but it also has high organic content. The conventional methods used today for treatment of WEEE cannot recycle 100%; they generate valuable fine residual fractions. For further processing of these residues, microwave pyrolysis has shown to be promising since it reduces the organic content and liberate enclosed metal pieces. However, to fully control the process, the dielectric properties of the materials need to be known but are difficult to determine due to the complex composition and structure of WEEE. This paper aims to describe a suitable procedure for determination of dielectric loss in six WEEE residual fine fractions and to correlate the results to heating behaviour during microwave pyrolysis. Three fractions are 'dusts' (light, medium and heavy dust) and three fractions are called 'particulate materials' and contain smaller particles (0–7, 0–20 and 7–12 mm). The method chosen was with a vector network analyser (VNA) using waveguide WR430 equipped with polymer foam to contain the samples which consisted of 1 dl of WEEE fine fraction. The scattering parameters were measured and dielectric loss in the materials was calculated. The measurements were performed in frequency region 1.3–2.7 GHz to include the industrial frequency 2.45 GHz. Differences between dielectric losses for the materials were determined by analysis of variance. It was shown that the scattering parameter measurements were rather stable for the dust materials and the losses could be determined. For the larger sized particulate materials a lot of reflection was observed during the measurements, due to fine metal wires in the material. The losses could be determined after removing these wires. The previously observed higher heating rate and shorter time for mass reduction of dusts could not be explained by differences in dielectric loss. However, since VNA measurements indicate that metal wires in the material disturb the field; presence of wires in the particulate materials might be one cause for slower heating rate and observed temperature drops during pyrolysis.

14/02562 Economic viability of biomass cofiring in new hard-coal power plants in Germany

Lüschen, A. and Madlener, R. *Biomass and Bioenergy*, 2013, 57, 33–47.

Biomass cofiring in coal power plants (with thermal contributions of typically 5–20%) is an interesting option to mitigate CO_2 emissions, since the additional costs are relatively minor and a secondary benefit is provided by the increased fuel flexibility. Worldwide, about 150 cofiring plants are in operation. In Germany, the electrical power potential for biomass cofiring in coal plants is about 28 TWh per annum, assuming a 10% replacement of coal combustion by biomass. In this paper, the authors studied the economic potential of biomass cofiring in hard coal power plants in Germany. To this end, they identified suitable biomass input fuels, investment and operating costs, and the profitability of cofiring investments. In a sensitivity analysis, the robustness of the results gained were checked, and in a Monte Carlo simulation uncertainties were explicitly taken into account. It was found that both regional and international biomass supplies are relevant, and that the cost-effectiveness of cofiring is strongly affected by the prices for biomass, coal and CO_2 permits, while investment and operating costs only have a modest influence. According to the calculations, electrical power generation costs attributable to biomass combustion for a plant put into operation in 2020 are between 70 and 75 € MWh^{-1}, while the average costs of biomass fuel from various sources and markets are calculated to be around 4.1 € GJ^{-1}.

14/02563 Effect of feedstock composition on product yields and energy recovery rates of fast pyrolysis products from different straw types

Tröger, N. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 158–165.

The conversion of different types of straw by fast pyrolysis has been investigated in this study. The mass and energy balance for corn stover, wheat straw and also rape and sunflower stalks are reported. A process development unit with a twin screw mixer reactor has been utilized for the experiments with a feeding rate of 10 kg/h at fixed operation conditions of reactor temperature, cooling temperature, vapour residence time, biomass particle size and heat carrier material. The results in product yields and energy recovery rates are compiled and compared. It can be observed that different types of straw produce different char, condensate and gas mass yields due to their varying ash content and differing lignocellulosic composition. On a dry and ash-free basis elemental formulas for feedstock, char, organic condensate and gas could be defined independent of the feedstock due to similar elemental compositions. Gas flow rate and composition measurements provide additional information on mass yields: a CO/CO_2-ratio of 1 (i.e. wood) corresponds to an organic condensate yield of about 50 wt%, whereas a ratio of 0.3–0.7 (straw) corresponds to about 18–32 wt%.

14/02564 Effect of flue gas recirculation during oxy-fuel combustion in a rotary cement kiln

Granados, D. A. *et al. Energy*, 2014, 64, 615–625.

The effect of flue gas recirculation (FGR) during oxy-fuel combustion in a rotary cement kiln was analysed by using a computational fluid dynamics (CFD) model applied to coal combustion process. The CFD model is based on three-dimensional balance equations for mass, species, energy and momentum. Turbulence and radiation model coupled to a chemical kinetic mechanism for pyrolysis processes, gas–solid and gas–gas reactions was included to predict species and flame temperature distribution, as well as convective and radiation energy fluxes. The model was used to study coal combustion with air and with oxygen for FGR between 30 and 85% as controller parameter for temperature in the process. Flame length effect and heat transfer by convection and radiation to the clinkering process for several recirculation ratios was studied. Theoretical studies predicted a located increase of energy flux and a reduction in flame length with respect to the traditional system which is based on air combustion. The impact of FGR on the oxy-fuel combustion process and different energy scenarios in cement kilns to increase energy efficiency and clinker production were studied and evaluated. Simulation results were in close agreement with experimental data, where the maximum deviation was 7%.

14/02565 Electrogenesis reduces the combustion efficiency of sewage sludge

Ma, J. *et al. Applied Energy*, 2014, 114, 283–289.

Electrogenesis in microbial fuel cells (MFCs) is a promising approach to extract useful energy from sewage sludge. However, its impact on ultimate sludge disposal (e.g. incineration) has not been well evaluated. In the present work, thermogravimetry and differential scanning calorimetry were carried out to investigate the combustion efficiency of recovered organic matter (ROM) and waste-activated sludge (WAS) in the electrogenesis process. In order to reduce the dimensionality of thermograms and to identify the predominant reactions, principal component analysis (PCA) was used for data processing. Two principal components were extracted from the derivative thermogravimetry, including three exothermic reactions associated with terrestrial organic matter, metabolic products, and acetylated substances. The variation of thermal kinetic characteristics revealed that energy densities of ROM and WAS were decreased after electrogenesis, and the thermograms shifted towards higher reaction temperatures, suggesting that electrogenesis might reduce the combustion efficiency of sewage sludge. Although no power was produced in open-circuit MFCs, more than 20% of the energy content of ROM and WAS was lost during the fermentation process, indicating that low Coulombic efficiency is inevitable in the treatment of sewage sludge with MFCs.

14/02566 Experimental evaluation of a 20 kW oxygen enhanced self-regenerative burner operated in flameless combustion mode

Sánchez, M. *et al. Applied Energy*, 2013, 111, 240–246.

Results are presented on the effects of oxygen enrichment on the performance of a flameless combustion furnace equipped with a regenerative burner. Natural gas was used as fuel (~97% CH_4) and the oxygen concentration in the combustion air was varied from 21% to 35% (volumetric percentage). The influence of oxygen enrichment on temperature and species profiles, pollutant emissions, thermal efficiency and regenerators effectiveness was quantified; measures were registered under steady state conditions for average wall temperatures of 880 °C. The results showed that for all oxygen enrichment rates it was possible to obtain the flameless combustion phenomena with its typical features, like no luminous effect, wide reaction zone and uniform temperature profile. A temperature peak of 1034 °C was measured for the operation with oxygen enriched air (35% O_2) compared to 975 °C when normal air (21% O_2) was used. NO_x emissions were below 5 ppm and the global efficiency increased almost 5% for an oxygen enriched level of 30%. Some comparisons to the burner operating without oxygen enrichment in conventional and flameless mode are presented to highlight the advantages of oxygen enhanced flameless combustion using self-regenerative burners.

14/02567 Gaussian process regression based optimal design of combustion systems using flame images

Chen, J. *et al. Applied Energy*, 2013, 111, 153–160.

With the advanced methods of digital image processing and optical sensing it is possible to carry out continuous imaging on-line in combustion processes. In this paper a method that extracts characteristics from the flame images is presented to immediately predict the outlet content of the flue gas. First, from the large number of flame image data, principal component analysis is used to discover the principal components or combinational variables, which describe the important trends and variations in the operation data. Then stochastic modelling of the combustion process is done by a Gaussian process with the aim to capture the stochastic nature of the flame associated with the oxygen content. The designed oxygen combustion content considers the uncertainty presented in the combustion. A reference image can be designed for the actual combustion process to provide an easy and straightforward maintenance of the combustion process.

14/02568 Investigation of the cigar burner combustion system for baled biomass

Repić, B. S. *et al. Biomass and Bioenergy*, 2013, 58, 10–19.

Biomass is deemed to be the main source of renewable energy in Serbia. Over the past couple of years, considerable efforts have been made to develop a technology which would enable biomass bales of various sizes and shapes to be used for energy production. A hot water boiler with cigarette type of combustion was constructed and used in the experimental investigation of biomass combustion phenomena. During the experiments performed, numerous parameters were measured: flue gas temperature, water temperature at the boiler inlet and outlet, while O_2, CO_2, CO, SO_2, and NO_x content in the flue gas was measured at the boiler outlet. Experiments were performed with biomass feed rate of 0.12 kg/s, mean boiler output of 1.56 MW and mean excess air coefficient of 2.1. During the steady state boiler operation, exhaust gas temperature was measured to be around 150–160 °C and obtained CO and NO_x emission rates were found to be quite acceptable. In addition, combustion of biomass bales in cigar burners was modelled by the means of appropriate numerical simulation. A good agreement between experimental and numerical results was obtained.

14/02569 Near-threshold photoionization mass spectra of combustion-generated high-molecular-weight soot precursors

Skeen, S. A. *et al. Journal of Aerosol Science*, 2013, 58, 86–102.
This study presents mass spectra showing organic species with mass-to-charge ratios between 15 and 900 sampled from near-atmospheric pressure, non-premixed, opposed-flow flames of acetylene, ethylene, and propane using an aerosol mass spectrometer with flash vaporization. Near-threshold photoionization was achieved by synchrotron-generated tuneable vacuum-ultraviolet (VUV) light. Among the three different fuels, variation was observed in the mass progression, peak intensities, and isomeric content identifiable in photoionization-efficiency curves. The results indicate that different pathways contribute to the molecular growth of soot precursors and that the significance of these mechanisms is likely to depend on the fuel structure and/or flame conditions. Previous work has highlighted thermodynamic propensities for precursor formation; however, the results suggest that kinetic mechanisms play a role in determining the partitioning of soot precursor isomers under the conditions investigated here. Evidence for aliphatic-bridged and oxygenated species was also observed. Such species have been proposed as a possible precursor to particle inception following cluster formation but have never been confirmed.

14/02570 Process simulation of oxy-fuel combustion for a 300 MW pulverized coal-fired power plant using Aspen Plus

Pei, X. *et al. Energy Conversion and Management*, 2013, 76, 581–587.
This work focuses on the amounts and components of flue gas for oxy-fuel combustion in a coal-fired power plant (CFPP). The combustion process of pulverized coal in a 300 MW power plant is studied using Aspen Plus software. The amount of each component in the flue gas in a coal-fired process, with air or O_2/CO_2 as an oxidizer, is obtained. The differences between the two processes are identified, and the influences of temperature, excess oxygen ratio and molar fraction of O_2/CO_2 on the proportions of different components in flue gas are examined by sensitivity analysis. The process simulation results show that replacing atmospheric air by a $21\%O_2/79\%CO_2$ mixture leads the decrease of the flame temperature from 1789 to 1395 °C. The equilibrium amount of NO_x declines obviously but the SO_x are still at the same level. The mass fraction of CO_2 in the flue gas increased from 21.3% to 81.5%. The amount of NO_x is affected sensitively by the change of temperature and the excess oxygen ratio, but the change of O_2/CO_2 molar fraction has a little influence to the generation of NO_x. With the increasing of O_2 concentration, the flame temperature and NO_x emissions enhance rapidly. When the molar fraction of O_2 increases to 30%, the flame temperature is similar and the mass fraction of NO_x is about one-eighth of that air atmosphere.

14/02571 Radial-profile and divergence measurements of combustion-generated soot focused by an aerodynamic-lens system

Headrick, J. M. *et al. Journal of Aerosol Science*, 2013, 58, 158–170.
The authors used light-scattering techniques to measure the angular divergence of a soot-particle beam produced by an aerodynamic-lens system in common use. Soot was generated in an atmospheric coflow ethylene diffusion flame and focused using this aerodynamic-lens system. The width of the beam generated was probed every $\sim 32\,\mu m$ over a range of more than 100 mm downstream of the exit nozzle by imaging laser light scattered from the particle beam onto an intensified CCD camera. The authors collected transmission electron microscopy (TEM) grids downstream of the exit nozzle and analysed the images to size the particles focused in the beam. The measurements yield a divergence angle in the range of 2.24–2.59 mrad corresponding to a solid angle of $1.59–2.11 \times 10^{-5}$ sr for a soot lognormal size distribution with an average projected area equivalent diameter of 88 nm and median of 73 nm. The authors characterized three similar aerodynamic-lens systems. The results demonstrate that the radial profile of the particle beam has more Gaussian character near the exit of the aerodynamic-lens system and is almost purely Lorentzian in character further downstream of the lens-system exit.

14/02572 Swirling flowfield for colorless distributed combustion

Khalil, A. E. E. and Gupta, A. K. *Applied Energy*, 2014, 113, 208–218.
Distributed combustion has been shown to provide significant improvements of gas turbine combustors performance including uniform thermal field in the entire combustion chamber (improved pattern factor), ultra-low emission of NO_x and CO, low noise, enhanced stability and higher efficiency. The flowfield associated with swirl is investigated to seek colourless distributed combustion. Non-reacting particle image velocimetry diagnostics is employed to determine the flow field characteristics of three different configurations with focus on velocity distribution, flow entrainment of reactive species, and turbulence. In all the configurations, air was injected tangentially into the combustor. The results for the configurations reported here represent both non-swirling 'linear' flow and swirling flow. Results showed that swirling flowfield configuration is characterized by higher flow velocities and much enhanced entrainment ratios throughout the combustor as compared to non-swirling case. Swirling flow exhibited high velocity region at the core of the combustor to further promote mixing and entrainment of reactive species. Higher velocities and entrainment are of significant importance in distributed combustion to prevent flame anchoring and enhance mixing. Experimental results are compared with numerical simulation for seeking improved flow distribution. The flowfield for different configurations are integrated with earlier data on emissions that showed near zero emission for swirling distributed combustion in gas turbine combustors.

14/02573 Tubular premixed and diffusion flames: effect of stretch and curvature

Pitz, R. W. *et al. Progress in Energy and Combustion Science*, 2014, 42, 1–34.
Tubular flames are ideal for the study of stretch and curvature effects on flame structure, extinction, and instabilities. Tubular flames have uniform stretch and curvature and each parameter can be varied independently. Curvature strengthens or weakens preferential diffusion effects on the tubular flame and the strengthening or weakening is proportional to the ratio of the flame thickness to the flame radius. Premixed flames can be studied in the standard tubular burner where a single premixed gas stream flows radially inward to the cylindrical flame surface and products exit as opposed jets. Premixed, diffusion and partially premixed flames can be studied in the opposed tubular flame where opposed radial flows meet at a cylindrical stagnation surface and products exit as opposed jets. The tubular flame flow configurations can be mathematically reduced to a two-point boundary value solution along the single radial coordinate. Non-intrusive measurements of temperature and major species concentrations have been made with laser-induced Raman scattering in an optically accessible tubular burner for both premixed and diffusion flames. The laser measurements of the flame structure are in good agreement with numerical simulations of the tubular flame. Due to the strong enhancement of preferential diffusion effects in tubular flames, the theory-data comparison can be very sensitive to the molecular transport model and the chemical kinetic mechanism. The strengthening or weakening of the tubular flame with curvature can increase or decrease the extinction strain rate of tubular flames. For lean H_2-air mixtures, the tubular flame can have an extinction strain rate many times higher than the corresponding opposed jet flame. More complex cellular tubular flames with highly curved flame cells surrounded by local extinction can be formed under both premixed and non-premixed conditions. In the hydrogen fuelled premixed tubular flames, thermal-diffusive flame instabilities result in the formation of a uniform symmetric petal flames far from extinction. In opposed-flow tubular diffusion flames, thermal-diffusive flame instabilities result in cellular flames very close to extinction. Both of these flames are candidates for further study of flame curvature and extinction.

Fire safety

14/02574 A constant pressure dust explosion experiment

Skjold, T. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 562–570.
A new apparatus has been designed for investigating flame propagation in turbulent dust clouds at near constant pressure conditions. The experimental approach is inspired by the classical soap bubble method for measuring burning velocities in gaseous mixtures. Combustible dust is dispersed with pressurized air to form an explosive mixture inside a transparent latex balloon. After a certain delay time, the turbulent dust cloud is ignited by a 40 J chemical igniter. A digital high-speed video camera records the propagating flame and the expansion of the balloon. Experiments were performed with two types of dust, *Lycopodium* spores and maize starch, as well as with propane–air mixtures under initially quiescent or turbulent conditions. Although the results are primarily qualitative in nature, they nevertheless demonstrate fundamental differences between premixed combustion of gaseous mixtures, and 'premixed combustion with non-premixed substructures' in mechanical suspensions of solid particles dispersed in air. The discussion highlights some fundamental challenges for future dust explosion research.

14/02575 A risk-based decision making approach to determine fireproofing requirements against jet fires

Badri, N. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 771–781.

API Publication 2218 is one of the most referred codes for fireproofing of onshore structural supports. Despite the extensive citation, it solely considers the effects of pool fire and rarely addresses jet fire outcomes. This absence of an explicit approach is common among all the other major references. Therefore, the objective of this paper is to introduce a new approach for determination of the necessity for fireproofing of structural supports against jet fires. For this purpose, the flame geometry and duration of jet fires are simulated for different leak sizes in identified fire potential sources. Then, following a worst-case analysis, those structures that may be impinged by long enough flames are screened out and then characterized by maximum impingement duration for fireproofing purpose. Moreover, each structure is assigned by a failure rate to estimate the degree of vulnerability through a detailed risk assessment. In this regard a new explanatory term called structure failure rate is introduced. This approach also enables researchers to quantify the effect of other protective systems (fire and gas detection, emergency shut-down, depressurization and firewalls) on the level of required fireproofing.

14/02576 Equivalent cloud methods used for explosion risk and consequence studies

Hansen, O. R. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 511–527.

The reactivity of a flammable gas mixture depends strongly on the concentration. Explosions can only take place between the lower and upper flammability limits (5–14% for methane), with by far the strongest explosions occurring near stoichiometry. When performing explosion studies to evaluate or minimize risk, optimizing design or ways to mitigate, many different approaches exist. Worst-case approaches assuming stoichiometric gas clouds filling the entire facility are often much too conservative and may lead to very expensive solutions. More refined approaches studying release scenarios leading to flammable clouds can give a more precise description of the risk (probabilistic approach) or worst-case consequences (realistic worst-case study). One main challenge with such approaches is that there can be thousands of potential release scenarios to study, e.g. variations of release location, direction, rate-profile, wind direction and strength. For each resulting gas cloud there can further be thousands of explosion scenarios as the transient non-homogeneous gas cloud can be ignited at a number of different locations and times. To reduce the number of explosion scenarios, in early 1990s GexCon developed a concept called equivalent stoichiometric clouds (ESC, initially called Erfac, later modified to Q5 and Q9) to linearize the expected hazards from arbitrary non-homogeneous, dispersed flammable gas clouds. The idea is that the potential explosion consequences from any non-homogeneous gas cloud can be approximated by exploding a smaller gas cloud at stoichiometric concentration. These concepts are in extensive use in explosion risk and consequence assessments. For probabilistic assessments all transient dispersion scenarios modelled may for each time step be given an ignition probability and an equivalent cloud size. For realistic worst-case assessments, the dispersed gas clouds may be ignited at the time when the estimated equivalent gas cloud has its maximum. Compared to alternative simplifications, e.g. applying faster and less accurate consequence models, the equivalent cloud method simplifications keep much of the precision required in an explosion study. Despite the wide acceptance and use of these methods, they have also been criticized for not being conservative enough or for being inaccurate, and some groups prefer a much more conservative approach substituting any predicted flammable gas cloud volume with the most reactive concentration. It is well known that explosion consequences may vary strongly when changing ignition location and other parameters, and one can therefore not expect that an equivalent cloud method will accurately reproduce any ignited gas cloud scenario (which has never been the goal), but rather provide a reasonable estimate of expected explosion consequences when used according to GexCon developed guidance. The currently recommended Q9 method works well for a range of scenarios, and for certain more confined or high reactivity scenarios a more conservative approach is recommended (Q8). For some scenarios the current approach has weaknesses, e.g. aerosols. This paper will describe different equivalent cloud methods, show examples of use and evaluate performance, and discuss weaknesses and potential improvements.

14/02577 Experiment-based investigations on the effect of ignition energy on dust explosion behaviors

Kuai, N. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 869–877.

Explosion behaviours of typical light metal and carbonaceous dusts induced by different ignition energies were investigated based on systematic experiments in a Siwek 20 L vessel. Comparative analysis reveals that the explosion mechanism of carbonaceous dust is the volatile combustion, whereas the mechanism for light metal dust mainly features the surface heterogeneous oxidation. Influences of ignition energy on severity and flammability limit are much more significant for carbonaceous dust than light metal, especially for the powder with less volatile. An innovative approach was introduced to derive flame thickness from the pressure–time trace. The relation between explosion induction time and combustion duration of ignitor was also analysed. Results show inappropriate ignition energy will cause under-/over-driving in the thermodynamic/kinetic characteristic measurements. In this way, a dimensionless parameter pressure ratio was introduced to evaluate the under-driving, while two methods by using flame thickness and induction time respectively, were proposed to evaluate over-driving. To improve the accuracy of dust explosion tests, authors advocate that explosion severity determination should be conducted at the critical ignition energy. Moreover, a comparison between the European and Chinese flammability limit determination procedures was also conducted, indicating that EN 14034–3 is suitable for light metal but not for carbonaceous, while GB/T 16425 appears to be slightly conservative for both carbonaceous and light metal dusts.

14/02578 Fire and explosion hazards related to the industrial use of potassium and sodium methoxides

Kwok, Q. *et al. Journal of Hazardous Materials*, 2013, 250–251, 484–490.

Sodium and potassium methoxides are used as an intermediary for a variety of products in several industrial applications. For example, current production of so-called ‘1G-biodiesel’ relies on processing a catalytic reaction called ‘transesterification’. This reaction transforms lipid resources from biomass materials into fatty acid methyl and ethyl esters. 1G biodiesel processes imply the use of methanol, caustic potash (KOH) and caustic soda (NaOH), the hazards of which are well known. The more recent introduction of the direct catalysts CH_3OK and CH_3ONa may potentially introduce new process hazards. From an examination of existing material safety data sheets concerning these products, it appears that no consensus currently exists on their intrinsic hazardous properties. Recently, l’Institut National de l’Environnement Industriel et des Risques of France and the Canadian Explosives Research Laboratory have embarked on a joint effort to better characterize the thermal hazards associated with these catalysts. This work employs the more conventional tests for water reactivity as an ignition source, fire and dust explosion hazards, using isothermal nano-calorimetry, isothermal basket tests, the fire propagation apparatus and a standard 20 L sphere, respectively. It was found that these chemicals can become self-reactive close to room temperature under specific conditions and can generate explosive dusts.

14/02579 Modelling blast induced damage from a fully coupled explosive charge

Onederra, I. A. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 58, 73–84.

This paper presents the hybrid stress blasting model (HSBM), one of the latest developments in the blasting engineering modelling field. HSBM includes a rock breakage engine to model detonation, wave propagation, rock fragmentation and muck pile formation. Results from two controlled blasting experiments were used to evaluate the code’s ability to predict the extent of damage. Results indicate that the code is capable of adequately predicting both the extent and shape of the damage zone associated with the influence of point-of-initiation and free-face boundary conditions. Radial fractures extending towards a free face are apparent in the modelling output and matched those mapped after the experiment. In the stage 2 validation experiment, the maximum extent of visible damage was of the order of 1.45 m for the fully coupled 38-mm emulsion charge. Peak radial velocities were predicted within a relative difference of only 1.59% at the nearest history point at 0.3 m from the explosive charge. Discrepancies were larger further away from the charge, with relative differences of −22.4% and −42.9% at distances of 0.46 and 0.61 m, respectively, meaning that the model overestimated particle velocities at these distances. This attenuation deficiency in the modelling produced an overestimation of the damage zone at the corner of the block due to excessive stress reflections. The extent of visible damage in the immediate vicinity of the blast hole adequately matched the measurements.

14/02580 Overpressure characteristics of aluminium dust explosion vented through a relief pipe

Yan, X.-Q. and Yu, J.-L. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 676–682.

A parametric experimental study of an aluminium dust explosion, initiated in a vessel and vented through a relief pipe, was performed. The aim is to clarify the overpressure characteristics in a vessel and relief pipe, during aluminium dust explosion venting, especially when a burn-up phenomenon occurs. For a vessel of fixed size, the influence of pipe diameter and pipe length on burn-up was discussed. Results demonstrate that burn-up occurs shortly after flame only enters the initial part of the relief pipe when the original dust concentration in the vessel is at relatively high level, which is usually higher than the optimum concentration obtained from the confined vessel. When burn-up occurs, the maximal overpressure continues to increase rather than to decay along the initial part of the relief pipe. If burn-up is vigorous, a second peak on overpressure-time curve in the vessel could appear. By adding 0.1 g aluminium powders on the membrane, the second overpressure peak may even surpass the first peak. Extending pipe lengths can strengthen the overpressures around the position where burn-up occurs in the relief pipe. Reducing the pipe diameter can increase the burn-up severity in the relief pipe owing to the increased dust concentration and the pressure accumulation.

14/02581 Post fire materials identification by micro-Raman spectroscopy and principal components analysis

Kerr, T. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 102, 103–113.

The chemical and physical characteristics of thermally damaged polymers, found in fire debris are studied using micro-Raman spectroscopy for identifying original materials in a fire compartment. Six polymeric materials commonly found in households were selected for the initial study. They are, polypropylene (DVD case), polystyrene foam (plates), polyurethane (sofa foam), polyester (PET curtains), ethylene vinylacetate (EVA shower curtains) and nylon (stockings). Raman shifts were obtained for each material prior to them, being burnt as the baseline for determining the loss of Raman bands due to a material modification by the fire. Each material was then burnt, and the subsequent Raman spectra collected. The average Raman spectra for each material were subjected to principal component analysis, which showed that after thermal decomposition, Raman spectroscopy could be used to identify and differentiate materials found in burnt debris. Raman spectra for each material were distinguishable in the sample group and could then be used for identification of the material in their post-fire state.

14/02582 TG–FTIR characterization of volatile compounds from flame retardant polyurethane foams materials

Chen, X. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 186–191.

Flame retardant polyurethane foams materials (PUFM) composites were prepared using tricresyl phosphate (TCP) as flame retardant. The combustion and thermal degradation behaviours of flame retardant PUFM composites were investigated by microscale combustion calorimetry (MCC) and thermogravimetric analysis (TGA)/infrared spectrometry (TG–IR). The results showed that TCP had excellent flame retardant abilities for PUFM. The TGA curves suggested that TCP has good ability of char formation. The volatilized products formed on thermal degradation of flame retardant PUFM indicated that the volatilized products are mainly carbonyl compounds, CO_2, and esters. In addition, TCP can greatly reduce the toxic gases containing –NCO groups and increase CO_2 as non-flammable gases when it is incorporated into the composites.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

14/02583 A re-assessment of elastic follow-up in high temperature piping

Boyle, J. T. *International Journal of Pressure Vessels and Piping*, 2013, 108–109, 7–12.

Despite the availability of detailed inelastic finite element analysis, the design of complex pipework systems operating at high temperature, where creep has to be taken into consideration, can be problematic. Design can be based on elastic analysis alone provided the effect of ‘elastic follow-up’ – the possibility of large inelastic strain concentration at some locations due to elastic behaviour of the rest – is somehow taken into account. Over the years it has become common to adopt an ‘elastic follow-up factor’, based on simplified methods, which can provide some estimate of the accumulated strain. This type of approach was developed over the years from numerous studies (including the author’s) of the phenomenon of elastic follow-up in various structures. In all of these studies the constitutive model for creep was based on the simple power law. However, it has recently been shown by the author that stress-range dependent constitutive creep models can lead to significantly different predictions for follow-up. This paper applies this finding to the author’s previous results on elastic follow-up in high temperature: it is demonstrated that consequently there could be a need to reassess current design practice.

14/02584 An activity-based-parametric hybrid cost model to estimate the unit cost of a novel gas turbine component

Langmaak, S. *et al. International Journal of Production Economics*, 2013, 142, (1), 74–88.

The first tool presented in this paper is a generic factory cost model that can estimate various costs at multiple levels of any manufacturing plant. The model is activity-based which means that the cost of each manufacturing operation is calculated and then summed up so that the true £-per-hour factory cost rate as well as the exact unit cost (i.e. manufacturing cost) of an unlimited number of different components can be estimated. The second tool is a scalable cost model that estimates the unit cost of future integrally bladed disc (blisk) designs which are used by the aerospace industry in gas turbine compressors. The tool multiplies the machine cost rates, calculated by the factory cost model, by the operation times derived from blisk scaling rules. As the operation times often depend on the number of blades, the disc diameter and other design variables, many scaling rules are based on the correlation between operation times and certain design parameters. Conversely, the remaining process times are constant because they are independent of the blisk geometry. As future process times can only be estimated and the correlation between operation times and design parameters is never perfect, all operation times have uncertainty distributions. These are cascaded through the model to generate a probability distribution of the unit cost. Through the interactive exchange of detailed cost information at the manufacturing operation level as well as extrapolated operation times, the two cost models facilitate design and manufacturing engineering to concurrently optimize blisk designs and manufacturing processes in terms of cost.

14/02585 Analysis of energy intensity in manufacturing industry using mixed-effects models

Kepplinger, D. *et al. Energy*, 2013, 59, 754–763.

The paper makes a cross-country analysis of the energy intensity in manufacturing sectors. Empirical data for this purpose is gathered from the databases of two international agencies namely the International Energy Agency and the UN International Development Organization, which provide energy consumption and manufacturing output data, respectively. The analyses are carried out with exploratory as well as formal statistical methods to identify the driving factors explaining energy intensity, identify trends and facilitate comparisons. The results from modelling the energy intensities with a linear mixed-effects model show some driving factors that explain the energy intensities. In general, the energy intensities of industrial sectors decreased around the world. In particular, industrialized countries with higher value of gross domestic product (GDP) per capita tend to have lower energy intensity indicating that efficiency in energy use is achieved along with the technological advancement. Countries with higher GDP and smaller population tend to have lower energy intensity values and a lower energy intensity index.

14/02586 Approaches for sustainable cement production – a case study from Turkey

Ekincioglu, O. *et al. Energy and Buildings*, 2013, 66, 136–142.

One of the ways to achieve sustainable construction goals in green projects is to select appropriate building materials. Such projects aim to use eco-friendly materials that encourage the consumption of recycled and renewable materials, locally manufactured with less harmful gas emissions with long and durable profiles. Using these eco-friendly materials is also helpful for obtaining higher rates during the application processes of green building certificates. As the demand for sustainable materials increases globally, construction material producers need to supply materials that can be used in environmentally responsible buildings without compromising ecological conditions. In particular, cement production has a huge impact on the environment because of releasing high amount of CO_2 during production processes. This paper aims to express the sustainability of building materials in Turkey’s construction industry by analysing cement production of a Turkish cement company where alternative fuels, raw materials, by-products and energy efficient methods are used for sustainable development.

14/02587 Chemical profile identification of fugitive and confined particle emissions from an integrated iron and steelmaking plant

Hleis, D. *et al. Journal of Hazardous Materials*, 2013, 250–251, 246–255.

The aim of this study is to obtain the characteristic inorganic chemical profile of important particle sources identified in the integrated iron and steel process: sintering, blast furnace, steelmaking and desulfurization slag processing. A complete chemical and physical characterization program was developed: particle size distribution, chemical analysis, X-ray diffraction, scanning electron microscopy with energy dispersive X-ray and thermogravimetric differential thermal analysis. The sample collected from the sinter stack showed high levels of K and Cl^-, followed by Fe, NH_4^+, Ca, Na and Pb. The profile of the dust samples taken from the sinter cake discharge zone was quite different, showing higher amounts of Fe, Ca and Al, and lower amounts of K, Cl^-, Na and Pb. Dust samples collected from the blast furnace (BF) and steelmaking cast house may be distinguished from each other based on the higher levels of Fe (hematite and magnetite) and lower levels of Ca, Zn and C (graphite) found in BF dust. High levels of Ca and Fe were found in samples taken from the desulfurization slag processing area. Such information can be useful for source apportionment studies at receptor sites that could be influenced by iron and steelmaking plant emissions.

14/02588 Energy and exergy analysis of an organic Rankine for power generation from waste heat recovery in steel industry

Kaşka, Ö. *Energy Conversion and Management*, 2014, 77, 108–117.

Energy, in conjunction with exergy, analysis of a waste heat driven organic Rankine cycle (ORC) is performed. Using actual plant data, performance of the cycle and pinpoint sites of primary exergy destruction are assessed. Furthermore, variations of energy and exergy efficiencies of the system with evaporator/condenser pressures, superheating and subcooling are illustrated. It is observed from the analysis that the energy and exergy efficiencies of the system are 10.2%; 48.5% and 8.8%; 42.2%, respectively, for two different actual cases. Exergy destruction of subcomponents is also quantified. The components with greater exergy destructions to lower one can be listed as evaporator, turbine, condenser and pump. Evaporation pressure has a significant effect on both energy and exergy efficiencies. Pinch-point analysis is also performed to determine effects of heat exchange process in the evaporator on the net power production.

14/02589 Energy efficiency benchmarking of energy-intensive industries in Taiwan

Chan, D. Y.-L. *et al. Energy Conversion and Management*, 2014, 77, 216–220.

Taiwan imports approximately 97.9% of its primary energy. Rapid economic development has significantly increased Taiwan's energy and electricity demands. Increased energy efficiency is necessary for industry to comply with energy-efficiency indicators and benchmarking. Benchmarking is applied in this work as an analytical tool to estimate the energy-efficiency indicators of major energy-intensive industries in Taiwan and then compare them to other regions of the world. In addition, the carbon dioxide emissions intensity in the iron and steel, chemical, cement, textile and pulp and paper industries are evaluated in this study. In the iron and steel industry, the energy improvement potential of blast furnace–basic oxygen furnace based on best practice technology is about 28%. Between 2007 and 2011, the average specific energy consumption of styrene monomer, purified terephthalic acid and low-density polyethylene was 9.6, 5.3 and 9.1 GJ/ton, respectively. The energy efficiency of pulping would be improved by 33% if best available technology were applied. The analysis results can serve as a benchmark for these industries and as a base case for stimulating changes aimed at more efficient energy utilization.

14/02590 Energy propagation in plasma arc welding with keyhole tracking

Li, Y. *et al. Energy*, 2014, 64, 1044–1056.

A three-dimensional mathematical model was developed to research the dynamic interaction between energy propagation and keyhole evolution in plasma arc welding. Particularly, a keyhole-tracking heat source model was proposed to reflect the energy propagation in the wake of keyhole evolution, which was tracked by the volume of fluid technique. The model consists of a Gaussian heat flux on top surface and a lower developing conical heat source related to the dynamic keyhole growth. In addition, a dynamic energy distribution coefficient was established, bound up with the keyholing process for the first time. The design of this heat transfer model introduces the analogy to actual energy propagation in experiment. Evolution of the dynamic energy density distribution concerning keyhole effect was analysed in details, and the corresponding temperature field was calculated and displayed to reveal the mechanism of thermal process in the workpiece. Furthermore, the keyholing process and molten metal flow in the weld pool were investigated to exhibit how the keyhole promotes the deep penetration welding. Finally, the experiments were carried out on the stainless steel plate, and the measured weld bead geometry, keyhole size and time for workpiece completely penetrated through were all close to simulation results.

14/02591 FGM elastoplastic analysis under thermomechanical loading

Nayebi, A. and Sadrabadi, S. A. *International Journal of Pressure Vessels and Piping*, 2013, 111–112, 12–20.

This paper studied the yield behaviours of a functionally graded material (FGM) spherical pressure vessel with power law material properties variations, under internal pressure and temperature gradient. Different material parameter variations were considered for two cases of (a) outer surface of the pressure vessel in steel and (b) inner surface in steel. It is shown that the combination of the yield internal pressure and temperature difference can causes yielding but it is strongly dependent of the material parameters variations. Cyclic loading of the pressure vessel in two cases was also studied. Based on the linear kinematic hardening, the plastic strain and stress were found in critical points.

14/02592 Improved energy efficiency in sawmill drying system

Anderson, J.-O. and Westerlund, L. *Applied Energy*, 2014, 113, 891–901.

The worldwide use of biomass has increased drastically during the past decade. At Swedish sawmills about half of the entering timber becomes lumber, with the remainder considered as by-product (biomass). A significant part of this biomass is used for internal heat production, mainly for forced drying of lumber in drying kilns. Large heat losses in kilns arise due to difficulties in recovering evaporative heat in moist air at low temperatures. This paper addresses the impact of available state-of-the-art technologies of heat recycling on the most common drying schemes used in Swedish sawmills. Simulations of different technologies were performed on an hourly basis to compare the heat and electricity demand with the different technologies. This was executed for a total sawmill and finally to the national level to assess the potential effects on energy efficiency and biomass consumption. Since some techniques produce a surplus of heat the comparison has to include the whole sawmill. The impact on a national level shows the potential of the different investigated techniques. The results show that if air heat exchangers were introduced across all sawmills in Sweden, the heat demand would decrease by 0.3 TWh/year. The mechanical heat pump technology would decrease the heat demand by 5.6 TWh/year and would also produce a surplus for external heat sinks, though electricity demand would increase by 1 TWh/year. The open absorption system decreases the heat demand by 3.4 TWh/year on a national level, though at the same time there is a moderate increase in electricity demand of 0.05 TWh/year. Introducing actual energy prices in Sweden gives an annual profit (investment cost excluded) on national level for the open absorption system of almost SEK580 million. For the mechanical heat pump technology the profit is SEK204 million and for the traditional heat exchanger the profit is significant lower. It has been found that a widespread implementation of available energy recovery technologies across Swedish sawmills would result in substantial savings of biomass for other purposes in the society.

14/02593 Improving energy efficiency of sawmill industrial sites by integration with pellet and CHP plants

Anderson, J.-O. and Toffolo, A. *Applied Energy*, 2013, 111, 791–800.

An essential strategy to lower energy and resources consumption is the development of highly integrated industrial sites including different kind of plants complementing one another. Sawmills are huge biomass suppliers to other industries, such as pulp and paper mills, pellet plants and combined heat and power (CHP) plants, and part of the biomass is also used for the internal heat requirement. In this paper the integration of a sawmill with a pellet plant and a CHP plant is investigated using advanced process integration techniques, so that the thermal energy and the electricity produced in the CHP plant by burning part of the sawmill biomass output are used for the heat and power requirements of the other two industries. The results show that up to 18% of the biomass by-products from the sawmill can be saved, but from the economic point of view the ratio between prices of the thermal energy sold for district heating and the low-quality biomass has to be lower than the present one to make the integrated design solution more attractive than separate plant operation.

14/02594 Inherent risk assessment methodology in preliminary design stage: a case study for toxic release

Shariff, A. M. and Zaini, D. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 605–613.

At preliminary design stage, process designers normally lack of information on the risk level from process plant. An inherently safer process plant could be designed if the information of risk levels could be known earlier at the preliminary design stage. If the risk level could be determined, there is a possibility to eliminate or reduce the risk by applying the well-known concept: inherent safety principle. This paper presents a technique to determine the risk levels at preliminary process design stage using a two-region risk matrix concept. A model to calculate the severity and likelihood of a toxic release accident was developed in Microsoft Excel spreadsheet. This model is integrated with process design simulator, iCON to allow for data transfer during preliminary design stage. two-region risk matrix is proposed and used to evaluate the acceptability of the inherent risk based on the severity and likelihood rating. If the inherent risk level is unacceptable, modification for improvement can be done using the inherent safety principles. A case study has been carried out to illustrate the benefit of applying this newly developed technique. It was successfully shown that an inherently safer plant could easily be designed by applying this technique.

14/02595 Input–output analysis of CO_2 emissions embodied in trade: a multi-region model for China

Su, B. and Ang, B. W. *Applied Energy*, 2014, 114, 377–384.

Energy-related CO_2 emissions embodied in international trade have been widely studied at the national level in recent years. The embodiment estimates help to explain the 'weak carbon leakage' between industrial and developing countries and to reveal the so-called 'consumption-based' emissions (or carbon footprint). These findings have implications on national climate policy and international negotiations. For a large country like China, spatial aggregation issues are important in embodied emission studies. Dividing the country into several regions, previous studies propose the hybrid emissions embodied in trade (HEET) approach for regional emission studies and use step-wise distribution of emissions embodied in trade (SWD-EET) analysis to explain indirect absorption patterns. This study combines the HEET approach and SWD-EET analysis to conduct a comprehensive study of China's regional emission embodiments. The authors explain how inter-regional trade and international trade affect China's regional domestic emissions, and present the resulting regional carbon footprint. Policy implications from the empirical results obtained are discussed.

14/02596 Integrated energy optimisation for the cement industry: a case study perspective

Swanepoel, J. A. *et al. Energy Conversion and Management*, 2014, 78, 765–775.

Energy costs play a major role in the cement production process. As much as 60% of total cost of production is allocated to energy and 18% to the consumption of electrical energy. Historically, energy cost savings were achieved by large infrastructure upgrades. These upgrades are often costly and lead to interruptions in production. In this paper, the operation of all the energy intensive components of the cement production process are identified, modelled, integrated and optimized for minimum operational costs while meeting production targets. This integrated approach allows for the simulation of the collective effect of individual production components. The system incorporates constraints such as maintenance, production and dynamic energy costs. No published research could be found where these constraints are incorporated into a single operational solution. The system was implemented on four cement plants and a total energy cost saving of 7% was achieved. This highlights the practical significance of an integrated approach to energy cost savings.

14/02597 Material pre-conditioning effects on the creep behaviour of 316H stainless steel

Mehmanparast, A. *et al. International Journal of Pressure Vessels and Piping*, 2013, 108–109, 88–93.

Material pre-conditioning by, for example, pre-strain through component bending and welding is known to alter the creep deformation and creep crack growth (CCG) behaviour of 316H stainless steel. Experimental test data on the creep deformation and crack growth behaviour of 316H weldment compact tension specimens at 550 °C, where the starter defect was introduced into the heat affected zone (HAZ), have been compared to those of obtained from similar specimens manufactured from parent material, which had been subjected to 8% compressive plastic pre-strain at room temperature. Similar degrees of accelerated cracking behaviour compared to parent material, for given values of C^*, were exhibited in both 316H HAZ and pre-compressed parent materials. This acceleration has been attributed to the influence of material hardening effects and the reduction of creep ductility in the pre-conditioned materials. These results are discussed in terms of the potential for using material pre-conditioning to assist in predicting the long term cracking behaviour of high temperature 316H stainless steel plant components from shorter term laboratory CCG tests.

14/02598 Methane potentials of the Swedish pulp and paper industry – a screening of wastewater effluents

Ekstrand, E.-M. *et al. Applied Energy*, 2013, 112, 507–517.

With the final aim of reducing the energy consumption and increase the methane production at Swedish pulp and paper mills, the methane potential of 62 wastewater effluents from 10 processes at seven pulp and/or paper mills (A–G) was determined in anaerobic batch digestion assays. This mapping is a first step towards an energy efficient and more sustainable utilization of the effluents by anaerobic digestion, and will be followed up by tests in laboratory-scale and pilot-scale reactors. Five of the mills produce kraft pulp (KP), one thermo-mechanical pulp (TMP), two chemical thermo-mechanical pulp (CTMP) and two neutral sulfite semi-chemical (NSSC) pulp. Both elementary and total chlorine free (ECF and TCF, respectively) bleaching processes were included. The effluents included material from wood rooms, cooking and oxygen delignification, bleaching (often both acid- and alkali effluents), drying and paper/board machinery as well as total effluents before and after sedimentation. The results from the screening showed a large variation in methane yields (percentage of theoretical methane potential assuming 940 N m L CH_4 per g TOC) among the effluents. For the KP-mills, methane yields above 50% were obtained for the cooking effluents from mills D and F, paper machine wastewater from mill D, condensate streams from mills B, E and F and the composite pre-sedimentation effluent from mill D. The acidic ECF-effluents were shown to be the most toxic to the AD-flora and also seemed to have a negative effect on the yields of composite effluents downstream while three of the alkaline ECF-bleaching effluents gave positive methane yields. ECF bleaching streams gave higher methane yields when hardwood was processed. All TCF-bleaching effluents at the KP mills gave similar degradation patterns with final yields of 10–15% of the theoretical methane potential for four of the five effluents. The composite effluents from the two NSSC-processes gave methane yields of 60% of the theoretical potential. The TMP mill (A) gave the best average yield with all six effluents ranging 40–65% of the theoretical potential. The three samples from the CTMP process at mill B showed potentials around 40% while three of the six effluents at mill G (CTMP) yielded 45–50%.

14/02599 Modelling the manufacturing history, through life creep-fatigue damage and limiting defect sizes of a pipework joint using finite element based methods

Stevens, M. J. *et al. International Journal of Pressure Vessels and Piping*, 2013, 108–109, 13–27.

The work reported in this paper describes a simulation of the manufacture, through-life operation and limiting defect size assessment of a pipework joint in a nuclear powerplant boiler. The objective of this work is to understand the critical factors that influence the integrity of the joint in-service and support accurate predictions of service life. This work differs from typical structural integrity assessments in that advanced modelling techniques have been used throughout the assessment process and include detailed simulations of the manufacturing process, a simulation of the entire in-service operating history including predictions of creep-fatigue damage and cracked body analysis to determine limiting defect sizes. Residual stresses resulting from the manufacturing process can be a key driver for creep and creep-fatigue damage. The calculation of creep-fatigue damage for assessment purposes is typically undertaken within the framework of an appropriate assessment code, such as EDF Energy's R5. The standard assessment approach usually requires calculation of stresses using elastic finite element analysis followed by hand calculations to calculate the damage. A combination of explicit and implicit finite element methods are employed to simulate a range of manufacturing processes which influence the in-service structural integrity of a branched pipework joint. Where available, test data have been compared to the results to assess the validity of the simulation. The simulation results then feed into a finite element-based structural integrity assessment. The methods follow the principles outlined in the EDF Energy R5 assessment code but use the inelastic strains calculated directly from analysis. The methods are based around the general purpose finite element code Abaqus. The residual stresses generated during manufacture may adversely affect the critical defect sizes for the pipework joint. However, the complex geometry and loading complicate the assessment of the cracked body. Therefore, a finite element analysis representing the cracked body has been carried out on the pipework joint to evaluate the J-integrals at the locations of interest and hence calculate the critical defect sizes. The analysis considers the residual stresses determined from the finite element analysis of the manufacturing processes.

14/02600 Numerical analysis of vortex core phenomenon during draining from cylinder tank for various initial swirling speeds and various tank and drain port sizes

Sohn, C. H. *et al. Journal of Hydrodynamics, Ser. B*, 2013, 25, (2), 183–195.

A dimple appears on a free surface while rotating a cylinder tank filled with liquid. The dimple starts to concentrically deeper to a drain port at the bottom centre of the tank. Over time, the dimple penetrates the drain port, a free surface forms a long and slender string shape in the tank, and a so-called vortexing (air core) phenomenon occurs. The generation of a vortex core depends on the size of the tank and drain port, and on the properties of the liquid in the tank. In this study, the liquid level and the time at which the vortex core is initially generated are numerically investigated using different values of tank diameter, drain port diameter, and initial tank rotational speeds. Instead of a full three-dimensional analysis, a two-dimensional axisymmetric simulation is conducted. The momentum conservation equation in the circumferential direction is additionally solved in the two-dimensional mesh system. Several non-dimensional variables are created: the ratio of the air core generation distance and tank diameter, the diameter ratio of the tank and drain port, the rotational Reynolds number, the rotational Froude number, and the rotational Weber number. Finally, the non-dimensional air core generation distance is correlated with the other non-dimensional parameters.

14/02601 Plant management tools tested with a small-scale distributed generation laboratory

Ferrari, M. L. *et al. Energy Conversion and Management*, 2014, 78, 105–113.

Optimization of power generation with smart grids is an important issue for extensive sustainable development of distributed generation. Since an experimental approach is essential for implementing validated optimization software, the University of Genoa has a laboratory facility for carrying out studies on polygeneration grids. The facility consists of two co-generation prime movers based on conventional technology: a 100 kWe gas turbine (mGT) and a 20 kWe internal combustion engine (ICE). The rig's high flexibility allows the possibility of integration with renewable-source-based devices, such as biomass-fed boilers and solar panels. Special attention was devoted to the thermal distribution grid design. To ensure the possibility of application in medium-large districts, composed of several buildings including energy users, generators or both, an innovative layout based on two ring pipes was examined. Thermal storage devices were also included in order to have a complete hardware platform suitable for assessing the performance of the different management tools. The test presented in this paper was carried out with both the mGT and the ICE connected to this innovative thermal grid, while users were emulated by means of fan coolers controlled by inverters. During this test the plant is controlled by a real-time model capable of calculating a machine performance ranking, which is necessary in order to split power demands between the prime movers (marginal cost decrease objective). A complete optimization tool (ECoMP program) was also used in order to obtain theoretical results considering the same machines and load values. The data obtained with ECoMP were compared with the experimental results to obtain a broad validation of the optimization tool.

14/02602 Reducing the energy consumption and CO_2 emissions of energy intensive industries through decision support systems – an example of application to the steel industry

Porzio, G. F. *et al. Applied Energy*, 2013, 112, 818–833.

The management of process industries is becoming in the recent years more and more challenging, given the stringent environmental policies as well as raising energy costs and the always-present drive for profit. A way to help plant decision makers in their daily choices is to refer to decision-support tools, which can give advice on the best practices on how to operate a plant in order to reduce the energy consumption and the CO_2 emissions keeping at the same time the costs under control. Such an approach can be useful in a variety of industries, particularly the most energy-intensive ones such as iron and steel industries. In this paper, an approach to the realization of a software system, which allows to generate internal reports on the plant performances, as well as to simulate the plant behaviour in different scenarios, is described. The main production processes (coke plant, blast furnace, steel shop, hot rolling mill) are described and simulated focusing on the prediction of products flow rates and composition, energy consumption and greenhouse gas emissions in different operating conditions. The importance of a correct management of the CO_2 within the plant is underlined, particularly with regard to the new European Union emissions trading system, which will be based on European benchmarks. The software tool is illustrated and a case study is included, which focuses on the simultaneous minimization of the CO_2 emissions and maximization of the profit through an optimized management of the by-product gases. The results from the case study show a good potential for process improvement, by a reduction in the cost and environmental impact.

14/02603 Technologies for utilization of industrial excess heat: potentials for energy recovery and CO_2 emission reduction

Viklund, S. B. and Johansson, M. T. *Energy Conversion and Management*, 2014, 77, 369–379.

Industrial excess heat is a large untapped resource, for which there is the potential for external use which would create benefits for industry and society. Use of excess heat can provide a way to reduce the use of primary energy and to contribute to global CO_2 mitigation. The aim of this paper is to present different measures for the recovery and utilization of industrial excess heat and to investigate how the development of the future energy market can affect which heat utilization measure would contribute the most to global CO_2 emissions mitigation. Excess heat recovery is put into a context by applying some of the excess heat recovery measures to the untapped excess heat potential in Gävleborg County in Sweden. Two different cases for excess heat recovery are studied: heat delivery to a district heating system and heat-driven electricity generation. To investigate the impact of excess heat recovery on global CO_2 emissions, six consistent future energy market scenarios were used. Approximately 0.8 TWh/year of industrial excess heat in Gävleborg County is not used today. The results show that with the proposed recovery measures approximately 91 GWh/year of district heating, or 25 GWh/year of electricity, could be supplied from this heat. Electricity generation would result in reduced global CO_2 emissions in all of the analysed scenarios, while heat delivery to a district heating system based on combined heat and power production from biomass would result in increased global CO_2 emissions when the CO_2 emission charge is low.

14/02604 The effective control of major industrial accidents by the major industrial accident prevention centers (MAPC) through the process safety management (PSM) grading system in Korea

Shin, I. J. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 803–814.

This paper examines effectiveness of a regulatory enforcement organization (major industrial accident prevention centre, MAPC), and a grading system for implementation of the process safety management (PSM) regulation in Korea. Many chemical installations have been built in Korea since the 1960s. The frequent occurrence of major industrial accidents has increased people's concerns. The Korean government enacted PSM regulations in 1996 in order to curb these accidents. However, a key question is how to make sure companies comply with the PSM regulations. In order to improve company's compliance with PSM regulations, the Ministry of Employment and Labour, responsible for the regulation, introduced a grading management system in 2001 and then established special supervisory centres for enforcement of PSM regulations in 2005. This paper reviews the role and effectiveness of the system in term of PSM enforcement. The author found that the grade-based approach has encouraged employers to implement the requirements of the PSM regulations. MAPCs play an effective role in enhancing enforcement performance. Although the more chemical plants have been established in Korea, the fewer major industrial accidents have occurred since the introduction of the system. The results may be useful for the policy maker to build an effective and efficient enforcement system.

14/02605 The effects of carbon prices and anti-leakage policies on selected industrial sectors in Spain – cement, steel and oil refining

Santamaría, A. *et al. Energy Policy*, 2014, 65, 708–717.

This paper assesses the impacts on the cement, steel and oil refining sectors in Spain of the carbon prices derived from the European Union's Emissions Trading Scheme (EU ETS), and the potential effect on these sectors of the EU anti-leakage policy measures. The assessment is carried out by means of three engineering models developed for this purpose. The results show a high exposure to leakage of cement in coastal regions; a smaller risk in the steel sector, and non-negligible risk of leakage for the oil refining sector when carbon allowance prices reach high levels. The authors also find that the risk of leakage could be better handled with other anti-leakage policies than those currently in place in the EU.

14/02606 Thermo-economic design optimization of parabolic trough solar plants for industrial process heat applications with memetic algorithms

Silva, R. *et al. Applied Energy*, 2014, 113, 603–614.

A thermo-economic design optimization of a parabolic trough solar plant for industrial processes with memetic algorithms is developed. The design domain variables considered in the optimization routine are the number of collectors in series, number of collector rows, row spacing and storage volume. Life cycle savings, levelized cost of energy and payback time objective functions are compared to study the influence on optimal design point location. Furthermore a multi-objective optimization approach is proposed to analyse the design problem from a multi-economic criteria point of view. An extensive set of optimization cases are performed to estimate the influence of fuel price trend, plant location, demand profile, operation conditions, solar field orientation and radiation uncertainty on optimal design. The results allow quantifying as thermo-economic design optimization based on short-term criteria as the payback time leads to smaller plants with higher solar field efficiencies and smaller solar fractions, while the consideration of optimization criteria based on long-term performance of the plants, as life cycle savings based optimization, leads to the reverse conclusion. The role of plant location and future evolution of gas prices in the thermo-economic performance of the solar plant has been also analysed. Thermo-economic optimization of a parabolic trough solar plant design for the reference industrial process heat application at a southern Mediterranean country considered in this work shows a levelized cost of energy of 5 c€/kW h.

14/02607 Time-of-use based electricity demand response for sustainable manufacturing systems

Wang, Y. and Li, L. *Energy*, 2013, 63, 233–244.

As required by the US Energy Policy Act of 2005, utility companies across the USA are offering time-of-use (TOU)-based electricity demand-response programmes. The TOU rate gives consumers opportunities to manage their electricity bill by shifting use from on-peak periods to mid-peak and off-peak periods. Reducing the amount of electricity needed during the peak load times makes it possible for the power grid to meet consumers' needs without building more costly back-up infrastructures and to help reduce greenhouse gas emissions. Previous research on the applications of TOU and other electricity demand-response programmes has been mainly focused on residential and commercial buildings while largely neglected industrial manufacturing systems. This paper proposes a systems approach for TOU-based electricity demand response for sustainable manufacturing systems under the production target constraint. The key features of this approach include: (i) the electricity-related costs including both consumption and demand are integrated into production system modelling; (ii) energy-efficient and demand-responsive production scheduling problems are formulated and the solution technique is provided; and (iii) the effects of various factors on the near-optimal scheduling solutions are examined. The research outcome is expected to enhance the energy efficiency, electricity demand responsiveness, and cost-effectiveness of modern manufacturing systems.

14/02608 Uncovering opportunity of low-carbon city promotion with industrial system innovation: case study on industrial symbiosis projects in China

Dong, L. *et al. Energy Policy*, 2014, 65, 388–397.

There is a dilemma for rapid industrializing China to balance economic growth and low carbonization. Industrial symbiosis (IS) provides a system innovation to utilize industry to fight climate change and pursue sustainable urban development, while little attention is paid in the literature. Under these circumstances, this study reviews the low-carbon city practice in China and conducts a case study to calculate the CO_2 emissions reduction potential under promoting IS projects in the two cities of Jinan and Liuzhou. With the real national project in Jinan as an advanced example, new scenarios related to IS are designed for Liuzhou, including comprehensive energy network, waste plastics recycling, scrap tyres recycling and fly-ash recycling. The material/waste and energy exchange is quantified in the IS network, as well as the related environmental benefit. The material/energy exchange is over 10 million tonnes and 20,000 tce in Jinan's case, and 2.5 million tonnes and 45,000 tce in Liuzhou's case. Results highlight that IS could effectively reduce CO_2 emissions. The total reduction potential amounts to 394,405,000 tCO_2/year and 234,788,000 tCO_2/year in Jinan and Liuzhou. Finally, policy implications on the ever-improvement of industrial symbiosis and China's sustainable urban development are proposed and discussed.

10 SPACE HEATING AND COOLING/HEAT PUMPS

14/02609 A conformal-mapping method for predicting the thermal properties of U-shaped borehole heat-exchangers

Liang, N.-W. *et al. Geothermics*, 2014, 50, 66–75.

This article investigates the thermal properties of U-shaped borehole heat-exchangers (UBHE), and the effects of related variables on the outlet temperature of UBHE. The conformal-mapping method, a simple and accurate thermal resistance calculation method, is employed to carry out UBHE design. The thermal analysis includes both the outside and the inside of the borehole. Outside the borehole, the finite line-source model calculates the wall temperature of the borehole in a steady state condition. Inside the borehole, the quasi-three-dimensional theory evaluates the temperature distribution of the working fluid. The results show that the conformal-mapping method yields an accurate solution for the outlet temperature of UBHE. The calculated solutions were compared with four cases of experimental data with good accuracy (within 6%). Under conditions of heat dissipation (cooling), the conformal-mapping method predicts results that are more accurate than the Hellström method (within about 1.33%). Sensitivity analysis shows that the heat backflow of UBHE can be reduced by increasing the distance of branch pipes and the liquid flow rate of the U-tube and reducing the depth of well.

14/02610 A numerical and experimental investigation on microscale heat transfer effect in the combined entry region in macro geometries

Kong, K. S. and Ooi, K. T. *International Journal of Thermal Sciences*, 2013, 68, 8–19.

The rising heat dissipation problem in electronic devices has led to numerous investigations on microchannel heat sink. However, literature shows that microscale heat transfer is generally not being applied to macro geometries, which is believed largely due to the fabrication and operational challenges. In this study, experiments were conducted in a conventionally sized circular channel which was manufactured through conventional techniques. The channel has a nominal diameter of 20 mm and length of 30 mm. An insert was placed concentrically into the channel to make the flow path small enough to behave like a microchannel in order to attain high heat removal capabilities. Under such a construction, various sizes of channel can be formed by placing different sizes of insert, one at a time, into the circular channel. The experiments and numerical simulations were conducted for nominal gap sizes of 1000 and 300 µm over a range of Reynolds numbers from 1000 to 5500 and heat fluxes from 5.3 to 37.1 W/cm^2 in the combined entry region. The experimental findings showed that the design was able to achieve a maximum heat transfer coefficient of 68 kW/m^2 K with single-phase water flowing through the annular channel of gap size of 300 µm at Reynolds number of 5200. Comparisons of measurements from the 300-µm case with the numerical solutions showed good agreement for pressure drop predictions with an average deviation of 4.5% but poor agreement for the Nusselt number predictions with deviation of more than 30% for cases at higher Reynolds number. Most importantly, the experiments have demonstrated the possibility of achieving microscale heat transfer effects in macro geometries using readily available conventional fabrication methods. With microscale heat transfer effects easily available, it also presents an opportunity to effectively improve the heat removal capabilities of a macroscale heat exchanger in the near future.

14/02611 A work procedure of utilising PCMs as thermal storage systems based on air-TES systems

Iten, M. and Liu, S. *Energy Conversion and Management*, 2014, 77, 608–627.

This paper seeks to offer a procedure to design an effective short-term thermal energy storage (TES) system using phase change materials (PCMs). The methodology focus on two main aspects: the selection of the working material and the heat exchanger development. The selection of the appropriate PCMs is a key feature for any TES, therefore their classifications, properties, advantages and disadvantages need to be investigated. The intensive research on this kind of material in recent years means that there are a range of commercial PCMs available and supplied by different companies. However, all types of PCM present their specific problems and therefore requirements are defined in order to select the most suitable material. Another key feature when designing TES systems is related to the heat exchanger formed by the PCM and the cold/hot heat sources. For this step, the choice of the appropriate container to encapsulate the PCM and the heat transfer enhancement techniques are analysed. Distinct methodologies such as experimental and numerical study methods and modelling software tools are presented to analyse the thermal energy performance of the system and achieve the optimal design of the TES system.

14/02612 An evaluation of robust controls for passive building thermal mass and mechanical thermal energy storage under uncertainty

Kim, S. H. *Applied Energy*, 2013, 111, 602–623.

Passive building thermal mass and mechanical thermal energy storage (TES) are known as one of state-of-the-art demand-side control instruments. Specifically, model-based predictive control (MPC) for this operation has the potential to significantly increase performance and bring economic advantages. However, due to the uncertainty in certain operating conditions in the field, its control effectiveness could be diminished and/or seriously damaged, which results in poor performance. This study pursues improvements of the control performance of both thermal inventories under uncertainty by proposing a robust MPC in which relevant uncertainty sources are compiled; therefore, it is designed to perform more stable than traditional MPCs under uncertain conditions. Uniqueness and superiority of the proposed robust demand-side controls include the following: (i) controls are developed based on the *a priori* uncertainty assessment, such that a systematic modelling approach for uncertainty was taken according to characteristics and classifications of uncertainty. (ii) The robust MPC reduces the variability of performance under varied and non-indigenous conditions compared to the deterministic MPC, and thus can avoid the worst case situation.

14/02613 Analysis of crossed van't Hoff metal hydride based heat pump

Muthukumar, P. and Satheesh, A. *International Journal of Hydrogen Energy*, 2013, 38, (26), 11415–11420.

In this paper, the operating feasibility of a single-stage metal based hydride heat pump (SS-MHHP) working on the principle of crossed van't Hoff line concept is presented. The performance of the system is predicted by solving the unsteady, two-dimensional mathematical model in an annular cylindrical configuration employing two different hydride alloy pairs, namely, $V_{0.846}Ti_{0.104}Fe_{0.05}/Fe_{0.9}Mn_{0.1}Ti$ and $V_{0.855}Ti_{0.095}Fe_{0.05}/MmNi_{4.7}Al_{0.3}$ (regeneration alloy/refrigeration alloy). The influences of heat source (T_H) and refrigeration (T_C) temperatures on the amount of hydrogen transferred between the paired reactors, coefficient of performance (COP) and specific cooling power (SCP) of the crossed van't Hoff SS-MHHP system are studied. Within the selected ranges of operating temperatures, the COP of the crossed van't Hoff SS-MHHP is about 60% higher than the conventional single-stage MHHP. The optimum operating temperatures of $V_{0.846}Ti_{0.104}Fe_{0.05}/Fe_{0.9}Mn_{0.1}Ti$ and $V_{0.855}Ti_{0.095}Fe_{0.05}/MmNi_{4.7}Al_{0.3}$ combinations are found to be 373/303/291 K and 400/303/283 K (heat source/heat sink/refrigeration temperatures), respectively. At the optimum operating temperatures, the COP and SCP of the $V_{0.846}Ti_{0.104}Fe_{0.05}/Fe_{0.9}Mn_{0.1}Ti$ and $V_{0.855}Ti_{0.095}Fe_{0.05}/MmNi_{4.7}Al_{0.3}$ combinations are 0.89 and 30.8 W/kg of total mass and 0.86 and 30.3 W/kg of total mass, respectively.

14/02614 Assessment of the actual hygrothermal performance of glass mineral wool insulation applied 25 years ago in masonry cavity walls

Stazi, F. *et al. Energy and Buildings*, 2014, 68, 292–304.

An experimental study was carried out on buildings constructed in the 1980s adopting vertical envelopes with a glass wool insulation layer in the cavity. The aims of this study are to evaluate the insulation conservation state after 25 years, to assess the actual indoor thermal comfort and to compare different retrofit interventions. The research included the following phases: laboratory tests on insulation samples to quantify any changes of morphological, chemical, physical and thermal proprieties of the material; detailed on-site monitoring in order to analyse the thermal comfort conditions; dynamic thermal simulations to assess the impact of different retrofit scenarios to satisfy the limits imposed by the current energy saving standard. The results show that the glass fibres and the binder were affected by a degradation process thus increasing both water absorption and thermal conductivity; thermal comfort and consumptions were not influenced by the insulation aging; the most effective retrofit is the introduction of an external insulation layer.

14/02615 Charging and discharging characteristics of cool thermal energy storage system with horizontal pipes using water as phase change material

Sait, H. H. and Selim, A. M. *Energy Conversion and Management*, 2014, 77, 755–762.

An experimental investigation of ice formation on cold vertical banks of horizontal tubes subjected to falling-film – jet mode – is conducted. In the charging process, a set of internally cooled vertical banks of horizontal tubes of brine is subjected to a falling film of water. The formed ice is periodically observed, photographed and measured in falling-film jet mode at specific internal coolant (ethylene–glycol solution) flow rates and temperatures. In the discharge process, the same solution is heated and used internally to release ice. Different thicknesses of the released ice are observed and measured. The maximum quantity of released ice is obtained and the optimum ice formation is determined. The results indicate that the ice formation and the solid ice released are controlled by the thermal resistance of the ice, time and pitch between tubes. The maximum gained ice has a thickness that is approximately equal to half of the tube spacing between the tubes utilized, which is formed in approximately 45 min and released in 12.5 min. The variation in heating solution temperature has a slight effect on the gained ice and discharging time.

14/02616 Condensation of the low GWP refrigerant HFC1234yf inside a brazed plate heat exchanger

Longo, G. A. and Zilio, C. *International Journal of Refrigeration*, 2013, 36, (2), 612–621.

This paper presents the heat transfer coefficients and the pressure drop measured during condensation of the new low global warming potential (GWP) refrigerant HFO1234yf inside a brazed plate heat exchanger: the effects of saturation temperature, refrigerant mass flux and vapour super-heating are investigated. The heat transfer coefficients show weak sensitivity to saturation temperature and great sensitivity to refrigerant mass flux. At low refrigerant mass flux ($<20\,kg\,m^{-2}\,s^{-1}$) the heat transfer coefficients are not dependent on mass flux and condensation is controlled by gravity. For higher refrigerant mass flux ($>20\,kg\,m^{-2}\,s^{-1}$) the heat transfer coefficients depend on mass flux and forced convection condensation occurs. The condensation heat transfer coefficients of super-heated vapour are from 8$% to 11% higher than those of saturated vapour. HFO1234yf exhibits heat transfer coefficients lower (10–12%) and frictional pressure drop lower (10–20%) than those of HFC134a under the same operating conditions.

14/02617 Development of an optimization strategy for insulation thickness of a domestic refrigerator-freezer

Yoon, W. J. *et al. International Journal of Refrigeration*, 2013, 36, (3), 1162–1172.

The optimization of insulation thickness is very important to increase the performance of domestic refrigerator–freezers (RFs) because of its strong dependency on the heat load through polyurethane-insulated compartments. However, it is very difficult to find the optimum insulation thickness to allow minimum energy consumption at the arbitrarily given coefficient of performance (COP) and internal volume of each compartment. In this study, the optimization process for the insulation thickness was proposed to improve the energy efficiency of a total RF system. This process included the quantitative relationships between the COP and the insulation thickness of each compartment. In addition, the effects of the proposed optimization strategy on the performance of RF were investigated in the bypass two-circuit cycle and the dual-loop cycle. As a result, the energy consumptions of the bypass two-circuit cycle and the dual-loop cycle were reduced by 5.7% and 6.1%, respectively, by applying the proposed optimization strategy.

14/02618 Dynamic performance of a novel solar photovoltaic/loop-heat-pipe heat pump system

Zhang, X. *et al. Applied Energy*, 2014, 114, 335–352.

This paper presents an investigation into the dynamic performance of a novel solar photovoltaic/loop-heat-pipe (PV/LHP) heat pump system for potential use in space heating or hot water generation. The fundamental equations governing the transient processes of solar transmission, heat transfer, fluid flow and photovoltaic (PV) power generation were appropriately integrated to address the energy balances occurring in different parts of the system, e.g. glazing cover, PV cells, fin sheet, loop heat pipe, heat pump cycle and water tank. A dedicated computer model was developed to resolve the above grouping equations and consequently predict the system's dynamic performance. An experimental rig was constructed and operated under the real weather conditions for over one week in Shanghai to evaluate the system living performance, which was undertaken by measurement of various operational parameters, e.g. solar radiation, photovoltaic power generation, temperatures and heat pump compressor consumption. On the basis of the first (energetic) and second (exergetic) thermodynamic laws, an overall evaluation approach was proposed and applied to conduct both quantitative and qualitative analysis of the PV/LHP module's efficiency, which involved use of the basic thermal performance coefficient (COP_{th}) and the advanced performance coefficient ($COP_{PV/T}$) of such a system. Moreover, a simple comparison between the PV/LHP heat-pump system and conventional solar/air energy systems was conducted. The research results indicated that under the testing outdoor conditions, the mean daily electrical, thermal and overall energetic and exergetic efficiencies of the PV/LHP module were 9.13%, 39.25%, 48.37% and 15.02% respectively, and the average values of COP_{th} and $COP_{PV/T}$ were 5.51 and 8.71. The PV/LHP module was found to achieve 3–5% higher solar exergetic efficiency than standard PV systems and about 7% higher overall solar energetic efficiency than the independent solar collector. Compared to the conventional solar/air heat pump systems, the PV/LHP heat pump system could achieve a COP figure that is around 1.5–4 times that for the conventional systems. It is concluded that the computer model is able to achieve a reasonable accuracy in predicting the system's dynamic performance. The PV/LHP heat pump system is able to harvest significant amount of solar heat and electricity, thus enabling achieving enhanced solar thermal and electrical efficiencies. All these indicate a positive implication that the proposed system has the potential to be developed into a high-performance PV/T technology that can contribute to significant fossil fuel energy and carbon dioxide emissions savings.

14/02619 Dynamics of external wall structures with a PCM (phase change materials) in high latitude countries

Chwieduk, D. A. *Energy*, 2013, 59, 301–313.

The main aim of the paper is to investigate the possibility of substituting the thick and heavy thermal mass external walls used in high latitude countries by thin and light thermal mass ones while maintaining similar comfort levels throughout the year. To make this substitution the use of phase change materials (PCM) panels incorporated into external wall structure are considered. The analysis of wall structures is carried out by modelling the energy balance of a room concentrating on the heat gains and losses through the walls. The resulting dynamic building model has been used in numerical simulations. Simulation studies have been performed for different types of wall structure under changing weather conditions. A wall with external PCM composite panel and its dynamic thermal performance is simulated and results analysed thermally. The results show that in a high latitude climate external light mass walls should contain insulation in an external layer if it is combined with a PCM panel Such lightweight external walls can substitute standard heavy mass walls comprised of insulation and brick (or concrete or other standard high thermal mass structure).

14/02620 Effect of heat transfer area and refrigerant mass flux in a gas cooler on heating performance of air-source transcritical CO_2 heat pump water heater system

Wang, S. *et al. Energy and Buildings*, 2013, 67, 1–10.

This study investigated the effect of geometrical parameters of gas coolers on system performance and the optimal discharge pressure with a developed and experimentally validated numerical model of an air-source transcritical CO_2 heat pump water heater system. This model considered the actual heat transfer process in the gas cooler and characteristics of the major components adopted in the prototype system. Simulation results showed a good agreement with experimental results in terms of heat yields, coefficient of performance and the optimal discharge pressure. Parametric analysis reveals that a larger heat transfer area of the gas cooler increases heat yields but decreases the optimal discharge pressure while other components in the system remain unchanged. In addition, with the same operating conditions and the same heat transfer area, heat yields increase with CO_2 mass fluxes by reducing tube diameters and flow passages of gas coolers, and beyond a certain range of mass fluxes, the optimal discharge pressure increases sharply. As one result, the optimal range of CO_2 mass flux in heat exchange tubes should be the range of 155–325 $\mathrm{kg\,m^{-2}\,s^{-1}}$ at the given condition in this study.

14/02621 Effect of inter-cooling on the performance and economics of a solar energy assisted hybrid air conditioning system with six stages one-rotor desiccant wheel

Elzahzby, A. M. *et al. Energy Conversion and Management*, 2014, 78, 882–896.

In this study, a mathematical model for predicting the performance of solar energy assisted hybrid air-conditioning system was considered. The desiccant wheels used a honeycombed silica gel–haloids composite material. This one-rotor desiccant wheel is divided into six stages, in which two-stage dehumidification process, two-stage pre-cooling process and two-stage regeneration process are realized. Three air streams are involved in the present system. The mathematical model has been validated with the experimental data. As the key operating and design parameter, the range of process air inlet temperature varied from 27.5 to 45 °C, the range of humidity ratio of the inlet process air varied from 9 to 21 g/kg, process air inlet velocity varied from 1.5 to 5.5 m/s have been examined for a range of rotation speeds from 6 to 20 rev/h. The optimization of these parameters is conducted based on the moisture removal capacity D, relative moisture removal capacity, dehumidification coefficient of performance, thermal coefficient of performance, and supply air temperature and humidity ratio. Finally, the influences of these main parameters on the optimal rotational speed are discussed and the life cycle cost analysis of the solar energy assisted hybrid air-conditioning system investigated.

14/02622 Effects of various carbon nanofillers on the thermal conductivity and energy storage properties of paraffin-based nanocomposite phase change materials

Fan, L.-W. *et al. Applied Energy*, 2013, 110, 163–172.

The effects of adding various carbon nanofillers on the thermal conductivity and energy storage properties of paraffin-based nanocomposite phase change materials (PCMs) for thermal energy storage were investigated experimentally. These included short and long multi-walled carbon nanotubes, carbon nanofibres, and graphene nanoplatelets (GNPs). For each type of the nanofillers, nanocomposite PCM samples with mass concentrations of 1–5 wt% at an increment of 1 wt% were prepared. The thermal conductivity of the samples in solid phase was measured using the transient hot-wire method at elevated temperatures. The energy storage properties, including melting/solidification temperatures and enthalpies, were measured using a differential scanning calorimeter. It was shown that the presence of the nanofillers slightly decreases the phase change enthalpies and has negligible influence on the phase change temperatures. The thermal conductivity of the nanocomposite PCMs was found to increase with raising the loading, while the relative enhancement strongly depends on the size and shape of the nanofillers. Of the four types of carbon nanofillers examined, GNPs were observed to cause greatest relative enhancement up to 164% at the loading of 5 wt%, due to their two-dimensional planar structure that leads to reduced filler/matrix thermal interface resistance, in contrast to the moderately decreased energy storage capacity of GNP-based nanocomposite PCMs.

14/02623 Experimental analysis of a paraffin-based cold storage tank

Torregrosa-Jaime, B. *et al. International Journal of Refrigeration*, 2013, 36, (6), 1632–1640.

The aim of this study is to characterize a paraffin-based cold storage tank. Novel experimental results are presented for this system which combines a significant amount of paraffin (1450 kg) immersed around 18 spiral-shaped coils disposed in counter-current flow. The paraffin has a phase-change temperature in the range 4–8 °C as measured by a three-layer calorimeter. Different tests have been carried out with a constant mass flow rate and supply temperature. Around 31% of the paraffin has hardly any contact with the coils and hereby acts as a dead mass. The results show the importance of natural convection within the phase-change-material, particularly during the melting process. The highest efficiency has been achieved for the lowest supply temperatures and mass flow rates of the heat transfer fluid.

14/02624 Experimental assessment of the energy performance of an advanced responsive multifunctional façade module

Favoino, F. *et al. Energy and Buildings*, 2014, 68, 647–659.

Responsive building elements (RBEs), renewable energy sources (RES) and energy storage within the building are considered as a key issue for the development of zero-energy/emission buildings. The exploitation at the building scale of RES and of the opportunities offered by the environment can be achieved through the ability of the RBEs to dynamically adapt to changing environmental conditions. Among various concepts, advanced integrated facades (AIFs) are probably one the most promising technologies, due to the important role that the building envelope plays in controlling the energy and mass flows between the building and the outdoor environment. In the framework of a research activity on AIFs, a new multifunctional facade module (MFM), called ACTRESS (ACTive, RESponsive and Solar) has been conceived and a prototype built to analyse the energy performance and the potentialities of such envelope components. The work presented in the paper introduces the MFM features and illustrates the results of an experimental campaign performed for the winter (heating) season.

14/02625 Experimental study of a two-stage adsorption freezing machine driven by low temperature heat source

Wang, J. *et al. International Journal of Refrigeration*, 2013, 36, (3), 1029–1036.

A novel two-stage adsorption freezing machine, which is powered by the heat source with the temperature below 100 °C was developed. The composite adsorbents of $CaCl_2$ and $BaCl_2$ developed by the matrix of expanded natural graphite were chosen as adsorbents. The performance of the system was tested, and the results showed that the system can generate the refrigerating power at −15 °C for the coolant temperature of 25 °C when the temperature of heat source is as low as 75 °C. For the heat source of 85 °C and the coolant temperature of 25 °C, the optimal coefficient of performance (COP) and specific cooling power (SCP) at −15 °C refrigeration are 0.127 and 100 $\mathrm{W\,kg^{-1}}$, respectively. COP and SCP increased with the increasing heat source temperature and decreased with the decreasing evaporating temperature; the influence of evaporating temperature is not as significant as that of the regeneration temperature.

14/02626 Fluid dynamic and heat transfer parameters in an urban canyon

Bottillo, S. *et al. Solar Energy*, 2014, 99, 1–10.

A microclimatic analysis in a typical urban configuration, has been carried out. Using a computational fluid dynamics method, a north–south-oriented urban street canyon, with a given height-to-width ratio, has been examined. The standard k–ε turbulence model has been used to simulate a three-dimensional flow field and to calculate the thermo-fluid dynamics parameters that characterize the street canyon. The aim of this study is to investigate the effect of solar radiation on the flow field and thermal parameters within the canyon. A comparison between transient and stationary simulations has been performed to evaluate the importance of considering the thermal inertia effects in an urban street canyon study. The dynamic characteristics of the three-dimensional flow in the canyon have been compared with other numerical simulations and experimental results. Furthermore a thermo-fluid dynamic analysis of natural convection effects on the heat transfer coefficient and turbulent kinetic energy, has been carried out.

14/02627 Heat transfer and pressure drop of natural refrigerants in minichannels (low charge equipment)

Cavallini, A. *et al. International Journal of Refrigeration*, 2013, 36, (2), 287–300.

The paper presents a comprehensive overview of the most recent research works on heat transfer (and pressure drop) with natural refrigerants in minichannels, aimed at proper design of heat transfer equipment. About boiling heat transfer, experimental heat transfer results are mainly fitted by empirical correlations referring to the common mechanisms used in more conventional geometries (nucleate and convective boiling); evaporation heat transfer through thin liquid film around vapour plugs is at times considered. About shear dominated condensation heat transfer, suggested design tools again mostly refer to the extension of the semi-empirical correlations earlier established for conventional geometries. For CO_2, heat transfer at supercritical conditions, such as in a gas cooler, is also treated. Finally the concept of the 'penalty factor' is applied to shear condensation in minichannels to establish the heat transfer performance of the different working fluids, the superior effectiveness of minitubes over macrotubes, and the optimization of minichannel condensers.

14/02628 Heat transfer performance and structural optimization design method of vertical phase change thermal energy storage device

Chen, C. *et al. Energy and Buildings*, 2014, 68, 679–685.

This research aims to further improve the thermal performance and the heat charge and discharge efficiency of the developed vertical phase change thermal energy storage device (VPCTESD) in order to adapt the application of VPCTESDs in solar energy utilization technology and waste heat utilization technology. Based on the developed heat transfer model of VPCTESD, with experiment and numerical simulation methods, this paper proposes the optimization design parameters of VPCTESD filled with phase change materials (called DX-53), including the gap between DX-53 slabs, the velocity of the heat transfer fluid (water) in the heat transfer unit's flow passage, the thickness of DX-53, the filling height of DX-53 and divergent length of entrance region. The research results provide the reference methods for evaluation of the thermal performance of VPCTESDs.

14/02629 Hydrocarbon working fluids for a Rankine cycle powered vapor compression refrigeration system using low-grade thermal energy

Li, H. *et al. Energy and Buildings*, 2013, 65, 167–172.

As natural fluids, several hydrocarbons with excellent thermophysical properties are recognized as alternative refrigerants to chlorofluorocarbons, hydrochlorofluorocarbons and hydrofluorocarbons. In this paper, the hydrocarbons including propane, butane, isobutane and propylene were used as working fluids in an organic Rankine cycle powered vapour compression refrigeration (ORC–VCR) system which was analysed and evaluated. With the overall coefficient of performance (COP) and working fluid mass flow rate of per kilowatt cooling capacity as key performance indicators, the results indicate that butane is the best refrigerant for the ORC–VCR system as the boiler exit temperature is between 60 and 90 °C, the condensation temperature varies from 30 to 55 °C and the evaporation temperature ranges from −15 to 15 °C. When the boiler exit temperature reaches 90 °C and the other input parameters are in typical values, the overall COP of the butane case reaches 0.470.

14/02630 Impact of a cool roof application on the energy and comfort performance in an existing non-residential building. A Sicilian case study

Romeo, C. and Zinzi, M. *Energy and Buildings*, 2013, 67, 647–657.

The vernacular Mediterranean architecture is characterized by passive solutions able to ensure thermal comfort conditions in the built environment during the hot season. The use of light colours to redirect most of the incident solar radiation was based on these traditional solutions. Cool roofs are a mix of ancient concepts and modern technologies; their application in new and existing buildings can significantly improve the energy efficiency during the cooling season and throughout the year. The paper reports the results of a large application in an office/laboratory building belonging to a school campus in Trapani, on the west coast of Sicily. The experiment was carried out in two phases. The building was continuously monitored during the first phase from late April to late September 2009: indoor and outdoor air temperatures, relative humidity and solar radiation were acquired. The monitoring was carried out before and after the cool eco-friendly white paint application, characterized by high solar reflectance and thermal emittance. The monitored data were used to calibrate the building model input into a dynamic simulation tool, used to evaluate the building performance with a number of variants. The analysis gave interesting results on the potential of this technique for the southern European climatic conditions.

14/02631 Latent heat storage in PCM containing mortars – study of microstructural modifications

Lucas, S. S. *et al. Energy and Buildings*, 2013, 66, 724–731.

The incorporation of phase change materials (PCM) into traditional mortars give these products the ability to store and release heat. In this way, it is possible to reduce the energy consumption and improve the thermal comfort in buildings. The introduction of micromaterials and nanomaterials in the mortar's matrix can cause microstructural changes that need to be addressed in order to optimize the PCM addition. The relationship between the hardened state performance of different PCM mortars, their internal microstructure and pore distribution has been observed for different binders such as lime, cement and gypsum. Their hardened state properties, microstructural modifications and heat storage capabilities were evaluated. The ability to store and release heat depends strongly on the size and distribution of internal pores and not only on the PCM content. Using a thermal efficiency test, an important correlation between thermal performance and the mortar's microstructure was established, for mortars with 0–30% of PCM added.

14/02632 Mixed convection heat transfer performance of water-based nanofluids in lid-driven cavity with wavy surfaces

Cho, C.-C. *et al. International Journal of Thermal Sciences*, 2013, 68, 181–190.

A numerical investigation is performed into the mixed convection heat transfer characteristics of water-based nanofluids confined within a lid-driven cavity. In modelling the cavity, it is assumed that the left and right walls have a wavy surface, while the upper and lower walls are both flat. In addition, it is assumed that the left wavy-wall has a constant heat flux, the right wavy-wall is maintained at a low temperature, and the upper and lower walls are both insulated and move horizontally. The analysis considers three different nanofluids, namely Cu–water, Al_2O_3–water and TiO_2–water. In performing the analysis, the governing equations are modelled using the Boussinesq approximation and are solved numerically using the finite-volume method. The simulations focus on the respective effects of the nanoparticle volume fraction, the type of nanofluid, the Richardson number, the Grashof number and the wavy surface geometry parameters on the mean Nusselt number. The results show that for all considered values of the Richardson number, the mean Nusselt number increases with an increasing volume fraction of nanoparticles. In addition, it is shown that the Cu–water nanofluid yields the best heat transfer performance of the three nanofluids. Furthermore, it is shown that the mean Nusselt number increases with an increasing Grashof number given a constant Richardson number. Finally, the results show that for a given nanofluid, the mean Nusselt number can be optimized via an appropriate tuning of the wavy surface geometry parameters.

14/02633 Modeling, planning and optimal energy management of combined cooling, heating and power microgrid: a review

Gu, W. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 26–37.

A combined cooling, heating and power (CCHP) microgrid with distributed cogeneration units and renewable energy sources provides an effective solution to energy-related problems, including increasing energy demand, higher energy costs, energy supply security, and environmental concerns. This paper presents an overall review of the modelling, planning and energy management of the CCHP microgrid. The performance of a CCHP microgrid from the technical, economic and environmental viewpoints are closely dependent on the microgrid's design and energy management. Accurate modelling is the first and most important step for planning and energy management of the CCHP microgrid, so this paper first presents an review of modelling of the CCHP microgrid. With regard to planning of the CCHP microgrid, several widely accepted evaluation methods and indicators for cogeneration systems are given. Research efforts on the planning methods of the CCHP microgrid are then introduced. Finally, the energy management of the CCHP microgrid is briefly reviewed in terms of cogeneration decoupling, control strategies, emission reduction and problem solving methods.

14/02634 Numerical and experimental investigation of a PCM-based thermal storage unit for solar air systems

Charvát, P. *et al. Energy and Buildings*, 2014, 68, 488–497.

A general problem of most solar thermal systems is the need for thermal storage in order to balance supply and demand of heat over a certain period of time. The possibility of employing latent heat of fusion in phase change materials (PCMs) for thermal energy storage in air-based solar thermal systems was investigated using laboratory experiments and numerical simulations. A heat storage unit containing 100 aluminium panels filled with a paraffin-based PCM was used in the investigations. The experiments were carried out in a laboratory environment with an electric air heater as a heat source. A numerical model of the unit was developed and implemented as a type in the TRNSYS 17 simulation tool. The results of the simulations with the developed model show a good agreement with experimental results. Subsequently, the model was used for a parametric study analysing the influence of certain parameters. The performed investigations showed a potential of the use of latent heat thermal storage in air-based thermal systems with a narrow temperature operation range.

14/02635 On variations of space-heating energy use in office buildings

Lin, H.-W. and Hong, T. *Applied Energy*, 2013, 111, 515–528.

Space heating is the largest energy end use, consuming more than seven quintillion joules of site energy annually in the US building sector. A few recent studies showed discrepancies in simulated space-heating energy use among different building energy modelling programmes, and the simulated results are suspected to be under-predicting reality. While various uncertainties are associated with building simulations, especially when simulations are performed by different modellers using different simulation programs for buildings with different configurations, it is crucial to identify and evaluate key driving factors to space-heating energy use in order to support the design and operation of low-energy buildings. In this study, 10 design and operation parameters for space-heating systems of two prototypical office buildings in each of three US heating climates are identified and evaluated, using building simulations with EnergyPlus, to determine the most influential parameters and their impacts on variations of space-heating energy use. The influence of annual weather change on space-heating energy is also investigated using 30-year actual weather data. The simulated space-heating energy use is further benchmarked against those from similar actual office buildings in two US commercial-building databases to better understand the discrepancies between simulated and actual energy use. In summary, variations of both the simulated and actual space-heating energy use of office buildings in all three heating climates can be very large. However these variations are mostly driven by a few influential parameters related to building design and operation. The findings provide insights for building designers, owners, operators, and energy policymakers to make better decisions on energy-efficiency technologies to reduce space-heating energy use for both new and existing buildings.

14/02636 Optimization of shell-and-tube heat exchangers conforming to TEMA standards with designs motivated by constructal theory

Yang, J. *et al. Energy Conversion and Management*, 2014, 78, 468–476.

A modified optimization design approach motivated by constructal theory is proposed for shell-and-tube heat exchangers in the present paper. In this method, a shell-and-tube heat exchanger is divided into several in-series heat exchangers. The Tubular Exchanger Manufacturers Association (TEMA) standards are rigorously followed for all design parameters. The total cost of the whole shell-and-tube heat exchanger is set as the objective function, including the investment cost for the initial manufacture and the operational cost involving the power consumption to overcome the frictional pressure loss. A genetic algorithm is applied to minimize the cost function by adjusting parameters such as the tube and shell diameters, tube length and tube arrangement. Three cases are studied which indicate that the modified design approach can significantly reduce the total cost compared to the original design method and traditional genetic algorithm design method.

14/02637 Optimization of thermoacoustic refrigerator using response surface methodology

Hariharan, N. M. *et al. Journal of Hydrodynamics, Ser. B*, 2013, 25, (1), 72–82.

Thermoacoustic refrigerators (TAR) convert acoustic waves into heat without any moving parts. The study presented here aims to optimize the parameters like frequency, stack position, stack length, and plate spacing involving in designing TAR using the response surface methodology (RSM). A mathematical model is developed using the RSM based on the results obtained from DeltaEC software. For desired temperature difference of 40 K, optimized parameters suggested by the RSM are the frequency 254 Hz, stack position 0.108 m, stack length 0.08 m and plate spacing of 0.0005 m. The experiments were conducted with optimized parameters and simulations were performed using the design environment for low-amplitude thermoacoustic energy conversion (DeltaEC) which showed similar results.

14/02638 Pickering emulsion: a novel template for microencapsulated phase change materials with polymer–silica hybrid shell

Yin, D. *et al. Energy*, 2014, 64, 575–581.

Microencapsulated phase change materials (MePCMs) with covalently bonded SiO_2/polymer hybrid as shell were fabricated via Pickering emulsion polymerization stabilized solely by organically modified SiO_2 particles. The morphology and core–shell structure of these microcapsules were observed by scanning electron microscopy. Thermal properties of microencapsulated 1-dodecanol were determined using differential scanning calorimetry and thermal gravimetric analysis. The results indicate that mass ratio of styrene (St)/divinylbenzene (DVB)/dodecanol has great effect on the morphology, inner structure, microencapsulation efficiency and durability of resultant MePCMs. When ratio of St/DVB/dodecanol was 5 : 1 : 12, dodecanol content of as much as 62.8% is obtained and the utility efficiency of dodecanol reaches 94.2%. The prepared MePCMs present good durability and thermal reliability. It was found that 2.2% of core material leached away the microcapsule after suspended in water for 10 days and 5.8% of core material leached after 2000 accelerated thermal cycling. This study demonstrated that Pickering emulsion polymerization is a simple and robust method for the preparation of MePCMs with polymer–inorganic hybrids as shell.

14/02639 Potential of natural ventilation in temperate countries – a case study of Denmark

Oropeza-Perez, I. and Østergaard, P. A. *Applied Energy*, 2014, 114, 520–530.

The objective of this article is to investigate the energy performance of natural ventilation as a passive cooling method of buildings within houses located in temperate countries using Denmark as a case study. The method consists in running simulations with a thermal–airflow programme of a household located in Vejle, during the months of June, July and August calculating the indoor air temperatures during this period. The dwelling belongs to a Danish project of passive houses named *Komfort Husene* where its users claim there are periods of overheating during the summer time. Then, after the simulations are validated with measured data, and by applying a new assessment method presented in this article as the cooling rate due to natural ventilation instead of a constant mechanical ventilation rate in the thermal balance within the dwelling, the energy saving is calculated. Results show that there is a reduction of 90% of hours of a possible use of mechanical ventilation, showing the feasibility to achieve thermal comfort within the house by using passive ventilation. The conclusion is therefore that the results contribute to an assessment of the economic and environmental benefits of using natural ventilation rather mechanical one on large-scale scenarios located in temperate conditions. Finally, as a practical implication example, an assessment for Denmark is carried out.

14/02640 Preparation and characterization of form-stable paraffin/polyurethane composites as phase change materials for thermal energy storage

Chen, K. *et al. Energy Conversion and Management*, 2014, 77, 13–21.

Polyurethane phase change material (PUPCM) has been demonstrated to be effective solid–solid phase change material for thermal energy storage. However, the high cost and complex process for the preparation of PUPCMs with a high enthalpy and a broad phase transition temperature range can prohibit industrial-scale applications. In this work, a series of novel form-stable paraffin/PUPCMs composites (*n*-octadecane/PUPCM, *n*-eicosane/PUPCM and paraffin wax/PUPCM) with high enthalpy and broad phase transition temperature range (20–65 °C) were directly synthesized via bulk polymerization. The composites were prepared at different mass fractions of *n*-octadecane (10, 20, 25, 30% w/w). The results indicated that the maximum encapsulation ratio for *n*-octadecane/PUPCM10000 composites was around 25% w/w. The chemical structure and crystalline properties of these composites were characterized by Fourier transform infrared spectroscopy, polarizing optical microscopy, wide-angle X-ray diffraction. Thermal properties and thermal reliability of the composites were determined using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). From DSC analysis, the composites showed a typical dual-phase change temperature. The enthalpy for the composite with 25% w/w *n*-eicosane was as high as 141.2 J/g. TGA analysis indicated that the composites degraded at considerably high temperatures. The process of preparation of PUPCMs and their composites was very simple, inexpensive, environmental friendly and easy to process into desired shapes, which could find the promising applications in solar energy storage and building.

14/02641 Preparation and thermal reliability of methyl palmitate/methyl stearate mixture as a novel composite phase change material

Xu, S. *et al. Energy and Buildings*, 2014, 68, 372–375.

In this study, a series of binary mixtures of methyl palmitate (MP) and methyl stearate (MS) were prepared, and their thermal properties were measured by differential scanning calorimetry, aiming for a novel composite phase change material (CPCM) for potential application in the warm area of China. The results indicate that the mixture consisting of 80 wt% MS and 20 wt% MP is optimum as the CPCM in terms of the phase change temperature ranges ($T_m = 25.52$–$40.38\,°C$; $T_f = 31.11$–$21.60\,°C$) and latent heats ($\Delta H_m = 164.1\,J/g$; $\Delta H_f = 154.9\,J/g$). In addition, the thermal reliability and chemical reliability of the CPCM were studied by accelerated thermal cycling test and Fourier transform infrared analysis. The results show that the CPCM has good thermal reliability and chemical stability.

14/02642 Radiation heat transfer in transient dust cloud flame propagation

Bidabadi, M. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 862–868.

This study investigates the impact of radiation heat transfer and heat conduction on dust cloud combustion. Radiation plays a very important role in the stability of dust cloud flame, and increasing the amount of radiation drastically raises the possibility of instability and explosion in a dust cloud mixture. Flame speed, which is a function of mixture characteristics, can exhibit a fluctuating behaviour. By using the discrete heat source method, it would be possible to study the transient propagation of dust flames. Thus, the propagation speed of flame can be obtained, and as time goes by, the transient speed of dust flame will reach its steady state value. By considering the radiation effect, better agreement is observed between the obtained results and experimental data.

14/02643 Radiative heat transfer analysis in pure scattering layers to be used in vacuum insulation panels

Jang, C. *et al. Applied Energy*, 2013, 112, 703–709.

Radiative heat transfer in the pure scattering layers in vacuum insulation panels is analysed using Monte Carlo method for two cases; for isotropic scattering and the other for pure backward scattering. The result for isotropically scattering medium agrees well with the diffusion solution within 1% error. This, indeed, shows that the diffusion approximation can be used as a good approximation in the tested cases. The results also suggest that the radiative heat transfer in the vacuum insulation panels can be effectively reduced by increasing the optical thickness of the core material and/or decreasing the surface emissivity by inserting more radiation shields. When the pure backward scattering is applied, significant reduction is found in the radiative heat transfer rate compared with the isotropic scattering case. It is shown that radiative thermal conductivity of the scattering layer is decreased to nearly half for the backward scattering medium when the optical thickness is large and the wall emissivity is high. Thus, the materials with highly backward scattering are recommended to be used as the core or insertion material between the radiation shields to enhance the performance of the vacuum insulation panels.

14/02644 Raw-water source heat pump for a vertical water treatment building

Oh, S. *et al. Energy and Buildings*, 2014, 68, 321–328.

A raw-water source heat pump for a thermal storage tank in a vertical water treatment building was dynamically simulated by TRNSYS. Two different configurations of a heat pump system with either one or two heat pumps were investigated by considering different heating zones in the building. The average coefficients of performance (COPs) of the single heat pump system were 4.79 and 3.76 for cooling and heating, respectively. When the size of the thermal storage tank was changed from 5 to 15 m^3, the highest COP was found at 10 m^3. The electric power consumption of the heat pump was significantly affected by weather conditions. The average COPs of the two-heat-pump system were 4.92 and 3.68 for cooling and heating, respectively. Except April and October the monthly average COP of the two-heat-pump system was higher than that of the single-heat-pump system.

14/02645 Review of thermal energy storage technologies based on PCM application in buildings

Pomianowski, M. *et al. Energy and Buildings*, 2013, 67, 56–69.

Thermal energy storage systems, using phase change materials (PCM) in buildings, are widely investigated technologies and a developing research area. Therefore, there is a need for regular and consistent reviews of the published studies. This review is focused on PCM technologies developed to serve the building industry. Various PCM technologies tailored for building applications are studied with respect to technological potential to improve the indoor environment, increase thermal inertia and decrease the energy use for a building. What is more, special attention is paid in this review to the discussion and identification of proper methods to correctly determine the thermal properties of PCM materials and their composites and as well procedures to determine their energy storage and energy saving potential. The purpose of this paper is to highlight promising technologies for PCM application in buildings with focus on room applications and to indicate in which applications the potential is less significant.

14/02646 Sintering of porous alumina obtained by biotemplate fibers for low thermal conductivity applications

Delbrücke, T. *et al. Journal of the European Ceramic Society*, 2013, 33, (6), 1087–1092.

In this research report, a sintering process of porous ceramic materials based on Al_2O_3 was employed using a method where a cation precursor solution is embedded in an organic fibrous cotton matrix. For porous green bodies, the precursor solution and cotton were annealed at temperatures in the range of 100–1600 °C using scanning electron microscopy and thermogravimetric analysis to obtain a porous body formation and disposal process containing organic fibres and precursor solution. In a structure consisting of open pores and interconnected nanometric grains, despite the low porosity of around 40% (calculated geometrically), nitrogen physisorption determined a specific surface area of 14 m^2/g, which shows much sintering of porous bodies. Energy dispersive X-ray and X-ray diffraction analytical methods revealed a predominant amount of α-Al_2O_3 in the sintered samples. Thermal properties of the sintered Al_2O_3 fibres were obtained by using the laser flash which resulted in the lower thermal conductivity obtained by α-Al_2O_3 and therefore improved its potential use as an insulating material.

14/02647 Synthesis and characterization of melamine–formaldehyde rigid foams for vacuum thermal insulation

Nemanič, V. *et al. Applied Energy*, 2014, 114, 320–326.

A novel core material for vacuum thermal insulation, the melamine–formaldehyde (MF) rigid foam was processed from an emulsion of the melamine–formaldehyde resin at temperatures between 130 and 150 °C, using pentane as the blowing agent. The achieved porosity was between 92% and 98%. Open pore structure with desired mechanical properties was achieved by variations of the initial chemical composition of liquid reactants and controlled foaming and hardening, employing classical heating. The average pore size was determined directly by scanning electron microscopy and indirectly by measuring the thermal conductivity in a wide pressure range from 10^{-3} mbar to the atmosphere. Optimization of the synthesis resulted in the base thermal conductivity equal to only 0.006 $W\,m^{-1}\,K^{-1}$ and an extremely low outgassing rate. The long-term pressure-rise measurements indicate that these MF rigid foams could be the first organic candidates applied as the core material in vacuum insulating panels whose performance may be comparable to selected inorganic core materials. Their further advantages compared to conventional organic foams are their stability, as they can withstand a temperature in excess of 200 °C, and good fire resistance.

14/02648 The influence of concrete density and conductivity on walls' thermal inertia parameters under a variety of masonry and insulation placements

Kontoleon, K. J. *et al. Applied Energy*, 2013, 112, 325–337.

In this study the variations of concrete density and concrete thermal conductivity of various wall assemblies are considered to analyse their influence on the dynamic thermal characteristics, such as the decrement factor and time lag. The assemblies under study refer to insulated walls with variable concrete density and the concrete placement in one or two layers. The insulation is also placed as one or two equivalent layers giving rise to a total of six typical wall configurations. The thermal inertia parameters are determined using the thermal-circuit modelling approach and the analysis is based on the nodal solution method. Density and conductivity variations of the concrete layers are seen to interrelate non-linearly with the walls' RC-sections corresponding parameters with consequences on its inertia parameters. As such variations, together with the studied insulation placements, affect the decrement factor and time lag in a different fashion, metrics for assessing the walls' thermal behaviour from a proportional and a relative point of view are introduced. Computer results, showing the impact of the variations of concrete density and conductivity on the decrement factor, time lag and the proposed metrics are presented for all the studied wall assemblies.

14/02649 Thermal analysis and modeling of surface heat exchangers operating in the transonic regime

Sousa, J. *et al. Energy*, 2014, 64, 961–969.

Surface coolers for tightly packed air-breathing propulsion are proposed to evacuate the heat loads from the lubrication circuit. This paper demonstrates the capability of integrated bypass-flow surface heat exchangers to cope with the high cooling demands from innovative engine architectures. This paper describes the experimental and numerical methodologies used to model the thermal performance of a surface cooler within an aero-engine. Experiments were carried out in a dedicated facility that reproduced transonic engine conditions, allowing the determination of surface temperature distribution with infrared thermography. The thermal convective process was characterized by means of an *ad hoc* three-dimensional inverse heat conduction approach. An unprecedented energy model was then developed to analyse the sensitivity of the heat exchanger capacity to different engine operating conditions. The results indicate that the investigated concept may provide up to 76% of the estimated lubrication cooling requirements during take-off of a modern gas turbine power plant.

14/02650 Thermal analysis of a ventilated facade with PCM for cooling applications

de Gracia, A. *et al. Energy and Buildings*, 2013, 65, 508–515.

A new type of ventilated facade with macro-encapsulated phase change material (PCM) in its air cavity is presented in this paper. The thermal performance of this special building envelope is experimentally tested to analyse its potential in reducing the cooling demand during the summer season in the continental Mediterranean climate. Two identical house-like cubicles located in Puigverd de Lleida, Spain, were monitored during summer 2012, and in one of them, a ventilated facade with PCM was located in the south wall. Six automatized gates were installed at the different openings of the channel in order to control the operational mode of the facade. This versatility allows the system to be used as a cold storage unit, as an overheating protection system or as a night free-cooling application. The experimental results show the night free-cooling effect to be the most promising operational sequence to reduce the cooling load of the cubicle. On the other hand, the thermal resistance of the outer skin of the facade must be increased; otherwise the cold storage system cannot be used efficiently.

14/02651 Thermal characterization of polymer matrix composites containing microencapsulated paraffin in solid or liquid state

Sari-Bey, S. *et al. Energy Conversion and Management*, 2014, 78, 796–804.

This paper focuses on the study of heat transfer mechanisms in composite materials that may be used for latent heat thermal energy storage applications. These composites contain phase change materials (PCMs) which can absorb and release energy during thermal cycling. The PCMs used here are paraffins microencapsulated in poly(methyl-methacrylate). Microencapsulation avoids the flow of paraffin when it is in the liquid state. Samples with different paraffin weight fractions and particles shape and distribution were studied in this work. Scanning electron microscopy and differential scanning calorimetry were used to determine morphology and perform measurements of phase changes temperatures, enthalpies and heat capacity, respectively. Further, a periodic method (DICO) allowed measuring thermal conductivity (λ) and diffusivity (a) of the composites at temperatures below and above of the paraffin phase change from crystalline solid to isotropic liquid.

14/02652 Thermal conductivity and latent heat thermal energy storage properties of LDPE/wax as a shape-stabilized composite phase change material

Trigui, A. *et al. Energy Conversion and Management*, 2014, 77, 586–596.

Phase change material (PCM) composites based on low-density polyethylene (LDPE) with paraffin waxes were investigated in this study. The composites were prepared using a melt-mixing method with a Brabender plastograph. The LDPE as the supporting matrix kept the molten wax in a compact shape during its phase transition from solid to liquid. Immiscibility of the PCMs (waxes) and the supporting matrix (LDPE) is a necessary property for effective energy storage. Therefore, this type of paraffin can be used in a latent heat storage system without encapsulation. The objective of this research is to use PCM composites as integrated components in a passive solar wall. The proposed composite Trombe wall allows daily storage of the solar energy in a building envelope and restitution in the evening, with a possible control of the air flux in a ventilated air layer. An experimental set-up was built to determine the thermal response of these composites to thermal solicitations. In addition, a differential scanning calorimetry analysis was carried out. The results have shown that most important thermal properties of these composites at the solid and liquid states, like the 'apparent' thermal conductivity, the heat storage capacity and the latent heat of fusion. Results indicate the performance of the proposed system is affected by the thermal effectiveness of phase change material and significant amount of energy saving can be achieved.

11 ENGINES

Power generation and propulsion, electrical vehicles

14/02653 Assessment of different technical options in reducing particle emissions from gasoline direct injection vehicles

Mamakos, A. *et al. Journal of Aerosol Science*, 2013, 63, 115–125.

This study assessed three different technical approaches targeting the control of particle number (PN) emissions from stoichiometric direct injection gasoline vehicles. The emission performance was evaluated under both the regulated New European driving cycle and the common artemis driving cycle, conducted at both 22 and −7 °C test cell temperatures. The most efficient measure was found to be the installation of a gasoline particulate filter which, with a filtration efficiency of more than 90%, effectively reduced the PN emission below the legislated diesel threshold of 6×10^{11} #/km, under all operating conditions examined. The use of 75–85% ethanol/gasoline blends on a flexi fuel vehicle resulted in large reductions in PN emissions, which spanned from approximately 20–35% under urban driving to an excess of 95% at motorway conditions. The emission performance of a Euro 4 vehicle utilizing a twin port/direct injection system verified the PN reduction potential offered by such strategies, exhibiting emissions in the $3\text{–}7\times10^{11}$ #/km range over all hot-start tests. The fraction of nano-sized non-volatile particles that could not be detected with the legislated PN measurement procedure ranged between 10% and 35%, that is within the levels reported for late technology diesel vehicles. The study also provided evidence of volatile artefact interference downstream of the volatile particle remover when employing condensation particle counters with a cut-off size below the legislated 23 nm.

14/02654 Combined effects of cooled EGR and a higher geometric compression ratio on thermal efficiency improvement of a downsized boosted spark-ignition direct-injection engine

Su, J. *et al. Energy Conversion and Management*, 2014, 78, 65–73.

The downsized boosted spark-ignition direct-injection (SIDI) engine has proven to be one of the most promising concepts to improve vehicle fuel economy. However, the boosted engine is typically designed at a lower geometric compression ratio (CR) due to the increased knock tendency in comparison to naturally aspirated engines, limiting the potential of improving fuel economy. On the other hand, cooled exhaust gas recirculation (EGR) has drawn attention due to the potential to suppress knock and improve fuel economy. Combing the effects of boosting, increased CR and cooled EGR to further improve fuel economy within acceptable knock tolerance has been investigated using a 2.0-litre downsized boosted SIDI engine over a wide range of engine operating conditions from 1000 to 3000 rpm at low to high loads. To clarify the mechanism of this complicated effects, the first law of thermodynamics analysis was conducted with the inputs from GT-Power engine simulation. Experiment results indicate that cooled EGR provides a greater brake thermal efficiency improvement than increasing geometric CR from 9.3 to 10.9. The benefit of brake thermal efficiency from the higher CR is limited to low-load conditions. The attributes for improving brake thermal efficiency by cooled EGR include reduced heat transfer loss, reduced pumping work and increased ratio of specific heats for all engine operating conditions, as well as higher degree of constant volume heat release only for the knock-limited high-load conditions. The combined effects of 18–25% cooled EGR and 10.9 CR lead to 2.1–3.5% improvements in the brake thermal efficiency (6–9% improvements in the fuel economy) compared to the baseline (9.3 CR without EGR). Among several effects contributing to the fuel economy improvement, the theoretical thermal efficiency improvement is primary. This is caused by increased ratio of specific heats and increased geometric CR. The reduction in heat transfer loss due to lower combustion temperature with EGR is the secondary effect.

14/02655 Combustion and emission characteristics of a diesel engine with DME as port premixing fuel under different injection timing

Wang, Y. *et al. Energy Conversion and Management*, 2014, 77, 52–60.

This work dealt with the combustion and exhaust performance of a dimethyl ether (DME) (methoxymethane) premixed charge compression ignition diesel engine. With the port premixing DME, the heat-release process was made up of the premixed charge homogeneous charge compression ignition combustion and diffusion combustion. The in-cylinder fuel injection timing and port premixing DME quantity played the important roles in combustion and emission control. They had little impact on the peak position of heat-release rate (HRR) during the low-temperature reaction (LTR) phase. However, they had great effects on the peak values and the crank-angle positions corresponding to the HRR peaks during the high-temperature reaction (HTR) and diffusion combustion phases. The peak value of HRR increased and the crank-angle corresponding to the HRR peak advanced with an incremental DME quantity or an early injection during HTR phase. However, the peak value of HRR dropped with an incremental DME quantity or a late injection during the diffusion combustion phase. $p_{\max}$ and $T_{\max}$ increased with an incremental DME quantity or an early injection. At the fixed direct-injection timing, brake-specific fuel consumption (BSFC) decreased slightly with a rise of DME quantity due to CA50 closer to top dead centre. At a fixed DME quantity, BSFC was lowest when diesel was injected into cylinder at 7° crank angle before top dead centre. Moreover, as more DME was aspirated from the port, NO_x emissions decreased at first but this decreasing trend eventually ceased. Smoke was reduced, but CO and HC were increased with a rise in DME volume. Meanwhile, like the conventional DICI operation, NO_x increased, but smoke, CO and HC declined with an early direct injection.

14/02656 Comparative evaluation of various methodologies to account for the effect of load variation during cylinder pressure measurement of large scale two-stroke diesel engines

Hountalas, D. T. *et al. Applied Energy*, 2014, 113, 1027–1042.

A significant number of fault-detection and fault-diagnosis methods are based on the use of the measured cylinder pressure to estimate critical engine parameters, i.e. cylinder brake power, fuel consumption, compression condition, injection timing, etc. But, the results derived from the application of these techniques depend strongly on the quality of data used. A common problem which has been identified by many researchers is load variation during cylinder pressure measurement. This for some applications (marine) can become significant and in some cases makes unusable utilization of cylinder pressure measurement. According to the conventional measurement technique for field applications, cylinder pressure is measured sequentially instead of simultaneously due to issues related mainly to cost, applicability and complexity. Because of this, the operating parameters that are estimated for each cylinder depend on instantaneous engine load. Therefore, when an operating problem or a mistuning is identified, the distinction for the actual cause (i.e. if it is attributed to a malfunction, mistuning or to engine load variation during measurement), is difficult because cylinders are not measured simultaneously. For this reason, in the present work, three methodologies that have been developed to account for the effect of load variation on diagnosis results are presented and evaluated in an attempt to be offered an alternative against simultaneous cylinder pressure measurement. For this purpose, a well-validated diagnostic technique, developed by the present research group, is employed and modified accordingly. The aforementioned methodologies have been applied on a large-scale two-stroke diesel engine used for power generation in a Greek island at two different operating conditions. From the application of each method, diagnosis and tuning results are derived which are then compared against the respective ones obtained from the conventional diagnosis technique which neglects the effect of load variation during measurement. The evaluation is based on the comparison of vital engine performance data, i.e. brake power output, cylinder fuel flow rate, peak firing pressure, ignition angle and compression quality. From the comparison of the diagnosis results it is revealed that the three methodologies provide adequate results while the one which is based on the use of two cylinder pressure sensors provides a very competitive alternative against simultaneous cylinder pressure measurement, offering the advantage of simplicity and low cost. Most important it is demonstrated the potential for all three methods to propose the required engine tuning to guarantee uniform cylinder operation despite variation of load during measurement.

14/02657 Diesel engine NO_x emissions control: an advanced method for the O_2 evaluation in the intake flow

Mariani, F. *et al. Applied Energy*, 2014, 113, 576–588.

In recent decades the increase of emissions regulations, along with the ever-increasing price of fuels and the request for more power from the engines, has pushed the world car industry to improve the performance of the applications of electronics, designed to control the internal combustion engines (ICE) and the pollutant emissions systems. At present, one of the main problems, in the development of diesel engines is represented by the achievement of an increasingly strict control on the systems used for the pollutant emission reduction. In particular, as far as NO_x gas is concerned, exhaust gas recycling (EGR) systems are mature and widely used, but increased efficiency in terms of emissions abatement, is necessary in order to determine as best possible the actual oxygen content in the charge at the engine intake manifold. The present work compares the ability of the artificial neural network (ANN) and neuro-fuzzy approach (ANFIS) to predict the volumetric oxygen concentration at the intake, using experimental data acquired on a compression ignition engine in transient operational conditions. In an off-line evaluation of results, both models show good predicting abilities; in particular the ANFIS model presents an absolute error value for the training and test phases equal to 0.7 and 0.9 (as a percentage of 3.5% and 4.5%), respectively, while the same evaluation obtained using the ANN-back propagation model provides 0.92 and 0.9 (as a percentage of 4.6% and 4.5%). The comparison shows that the ANFIS model produces more accurate solutions in less time, using linear rules that bind the input variables with the output. The linearity of the rules is a key feature to decrease the convergence time especially when the model is used for the on-board periodic training activity due to the aging of the engine.

14/02658 Estimation of performance variation of future generation IGCC with coal quality and gasification process – simulation results of EU H2-IGCC project

Majoumerd, M. M. *et al. Applied Energy*, 2014, 113, 452–462.

The integrated gasification combined cycle (IGCC) power plant delivers environmentally benign power from coal. The overall objective of the European Union (EU)'s H2-IGCC project is to develop and demonstrate technological solutions for future generation IGCC plants with carbon capture. As a part of the general goal, this study evaluates the effects of coal quality and the selection of gasifiers on the overall performance of the baseline configuration of the IGCC plant. Four commercially available gasifiers, namely Shell, GE, Siemens and ConocoPhillips gasifiers, are considered for this comparative study. The effects of three different types of coals on the gasification processes have been investigated, as well as the overall performance of the plant. Simulation results show that slurry-fed gasifiers are not suitable for lignite coal, while dry-fed gasifiers are less sensitive to coal quality. Coal quality has the greatest effect on the GE gasifier. The ConocoPhillips gasifier demonstrates the highest cold gas efficiency using bituminous coal. The coal rank and the gasification process have relatively less effect on gas turbine power output, while steam turbine power output varies significantly with these. Although steam turbine power output increases with a reduction in coal quality, especially for slurry-fed gasifiers, the air separation unit power demand offsets this increase. The highest overall plant efficiency is 37.6% (LHV basis) for the GE gasifier and coal B. The lowest overall efficiency penalty with coal quality is 5% (LHV basis) for the Shell gasifier with input changed from bituminous to lignite. Moreover, simulation results show that GE's gasification technology has the highest CO_2 emissions for lignite coal, i.e. 158 g/kWh.

14/02659 Exergoeconomic, sustainability and environmental damage cost analyses of T56 turboprop engine

Balli, O. and Hepbasli, A. *Energy*, 2014, 64, 582–600.

The main objective of this study is to assess the performance of T56 turboprop engine using the exergoeconomic, sustainability and environmental damage cost analysis methods at different power loadings. The unit exergy cost of the shaft power decreases from \$76.34/GJ at 75%-mode to \$58.32/GJ at takeoff-mode due to increasing the shaft power. The unit exergy cost of the kinetic exergy increases from \$599.43/GJ at 75%-mode to \$666.76/GJ at takeoff-mode because of the unit exergy cost of the exhaust gaseous with the increase in the fuel flow. The sustainability analysis indicates that the gas turbine has the highest sustainability index. Increasing the fuel flow rate raises the environmental pollutants and the environmental damage cost rate. The environmental damage cost rates of the engine are calculated to be \$423.94/h at 75%-mode, \$576.97/h at 100%-mode, \$634.93/h at military-mode and \$665.85/h at takeoff-mode. The total cost rate consists of the sum of the fuel cost, the capital investment cost, the operating and maintenance costs, and the environmental damage cost. The total cost rates of the engine are determined to be \$1702.59/h at 75%-mode, \$2100.26/h at 100%-mode, \$2220.42/h at military-mode and \$2284.50/h at takeoff-mode.

14/02660 Gas turbine with heating during the expansion in the stator blades

El-Maksoud, R. M. A. *Energy Conversion and Management*, 2014, 78, 219–224.

Reheating is used in a gas turbine to achieve a higher power output. However, the reheat process is constrained by the heat quantity given to it and the choice of reheat point. Consequently, this paper introduces a new gas turbine cycle to overcome the reheat drawbacks and having superior features. In this cycle, the reheat process is replaced by processes of heating the expanded gases while passing through different turbine stator blades. A small amount of combusted gases is utilized to flow inside such blades for heating and mixing with the expanded gases. Nevertheless, this is performed with the precaution of turbine overheating by reducing the maximum temperature of the present cycle significantly. The simulated results demonstrate that the cycle performance is increased by raising the quantity of heating during the expansion. Additionally, this cycle achieves greater efficient output than the traditional reheat Brayton cycle operating with higher maximum cycle temperature. To boost the present cycle efficiency, regeneration is used making the possibility of such cycle to be competitive to the combined cycle.

14/02661 Operating maps of a rotary engine used as an expander for micro-generation with various working fluids

Antonelli, M. *et al. Applied Energy*, 2014, 113, 742–750.

The determination of the most suitable operative fluid for the various types of organic Rankine cycle expansion machines has been the object of an abundant literature. In this study, an analysis was carried out in a rotary volumetric expander based on the Wankel concept, which was never studied before for this application. This paper is focused in assessing the proper coupling between the temperature at which the heat is available, and hence the saturation temperature at the inlet, and the working fluid that is to be used in an expander of given displacement to get the desired mechanical power. This analysis was carried out by means of a numerical model of the expander that was validated by comparison with the data measured at the dyno on a prototype that was built at the University of Pisa and operated with compressed air. The comparison was carried out in terms of indicated pressure, delivered torque and working fluid mass flow rate. The operative maps of this expander were evaluated by considering the working conditions that give an isentropic efficiency higher than a fixed value. By this way, it was possible to evaluate the relationship between the used working fluid, the inlet temperature and the delivered mechanical power.

14/02662 The effect of hydrogen addition on combustion and emission characteristics of an n-heptane fuelled HCCI engine

Guo, H. and Neill, W. S. *International Journal of Hydrogen Energy*, 2013, 38, (26), 11429–11437.

The mechanisms of the influence of hydrogen enrichment on the combustion and emission characteristics of an n-heptane fuelled homogeneous charge compression ignition (HCCI) engine was numerically investigated using a multi-zone model. The model calculation successfully captured the most available experimental data. The results show that hydrogen addition retards combustion phasing of an n-heptane fuelled HCCI engine due to the dilution and chemical effects, with the dilution effect being more significant. It is because of the chemical effect that combustion duration is reduced at a constant compression ratio if an appropriate amount of hydrogen is added. As a result of retarded combustion phasing and reduced combustion duration, hydrogen addition increases indicated thermal efficiency at a constant combustion phasing. Hydrogen addition reduces indicated specific unburned hydrocarbon emissions, but slightly increases normalized unburned hydrocarbon emissions that are defined as the emissions per unit burned n-heptane mass. The increase in normalized unburned hydrocarbon emissions is caused by the presence of more remaining hydrocarbons that compete with hydrogen for some key radicals during high temperature combustion stage. At a given hydrogen addition level, N_2O emissions increases with overly retarding combustion phasing, but hydrogen addition moderates this increase in N_2O emissions.

14/02663 The effects of unburned hydrocarbon recirculation on ignition and combustion during diesel engine cold starts

Cui, Y. *et al. Energy*, 2014, 64, 323–329.

Exhaust gases contain large amounts of unburned hydrocarbons during cranking without combustion. The effects of unburned hydrocarbon recirculation on ignition and combustion during diesel engine cold starts were investigated using both experiments and simulations. Experiments were conducted on a single-cylinder direct injection diesel engine equipped with a common rail injection system. The amount of unburned hydrocarbon recirculation was jointly controlled by an exhaust gas recirculation valve and a back pressure valve. The investigation showed that optimal opening of recirculation control valves allowed the first firing cycle to be advanced from 19 to six and reduced the duration of heavy smoke emission (opacity > 50%) by 77%. However, the enhancement to the in-cylinder low temperature reaction (LTR) decreased gradually as the amount of unburned hydrocarbon recirculation increased. An analysis of the chemical kinetics showed that the reaction intermediates present in unburned hydrocarbons, such as ketohydroperoxides, were the most significant factor in enhancing the LTR during non-firing cycles. At the same time, the substantial heat capacity of unburned hydrocarbons suppressed the LTR for higher recirculation rates.

14/02664 The effects of using biodiesel on CI (compression ignition) engine and optimization of its production by using response surface methodology

Abuhabaya, A. *et al. Energy*, 2013, 59, 56–62.

Bio-fuel production provides an alternative non-fossil fuel without the need to redesign current engine technology. This study presents an experimental investigation into the effects of using biodiesel blends on diesel engine performance and its emissions. The biodiesel fuels were produced from sunflower oil using the transesterification process with low molecular weight alcohols and sodium hydroxide then tested on a steady state engine test rig using a Euro 4 four-cylinder compression ignition engine. This study also shows how by blending biodiesel with diesel fuel at intervals of B5, B10, B15, and B20 can decrease harmful gas emissions significantly while maintaining similar performance output and efficiency. Production optimization was achieved by changing the variables which included methanol/oil molar ratio, NaOH catalyst concentration, reaction time, reaction temperature, and rate of mixing to maximize biodiesel yield. The technique used was the response surface methodology. In addition, a second-order model was developed to predict the biodiesel yield if the production criteria is known. The model was validated using additional experimental testing. It was determined that the catalyst concentration and molar ratio of methanol to sunflower oil were the most influential variables affecting percentage conversion to fuel and percentage initial absorbance.

14/02665 The heat release analysis of bio-butanol/gasoline blends on a high speed SI (spark ignition) engine

Deng, B. *et al. Energy*, 2013, 60, 230–241.

In this study, experiments were conducted on a single-cylinder high speed spark ignition (SI) engine fuelled with 30 and 35%vol butanol/gasoline blends and compared to the pure gasoline. This research is trying to find out the common principles about the influence on combustion heat release of SI engine for variables such as ignition timing, engine load, and butanol blend ratio in a wide engine speed range (3000–8500 rpm). The results showed that butanol provides higher knocking resistance by allowing advance the ignition timing in SI engines, leading to more efficient combustion. The laminar burning velocity of butanol is higher than that of gasoline, but that does not guarantee a faster burning speed in a real engine unless the combustion process is more reasonably organized, such as using the optimum ignition timing. In the overall trend, as the butanol blend ratio increasing, one can achieve a more efficient combustion process with using the optimum operating parameters. Obviously, the rate of heat release became slower and declined in peak value as the engine load decreases, accompanied by a shift of peak value to later for both pure gasoline and butanol/gasoline blends. In the aspect of fuel oxidation rate, the fuel–air ratio is the dominated factor rather than fuel type.

Hybrid engine systems

14/02666 Characterization of a diesel engine operating with a small proportion of methanol as a fuel additive in biodiesel blend

Mat Yasin, M. H. *et al. Applied Energy*, 2014, 114, 865–873.

Biodiesel has been a lucrative commodity in the current global economic trade as there is mounting concern for issues relating to the environment and oil depletion. Biodiesel has been proven to be the next alternative renewable fuel as it is environmentally friendly, sustainable and possesses similar combustion characteristics to petroleum diesel. However, due to the higher density and viscosity of biodiesel, pure biodiesel is not widely used in diesel engines. Therefore, the purpose of alcohol as a fuel additive is to improve the viscosity and density in the biodiesel blend. The focus of this study is to evaluate the performance and emissions of a small proportion of methanol (5% by volume) in a B20 blend and mineral diesel separately. A compression ignition (CI) Mitsubishi 4D68 multi-cylinder DI diesel engine was used in this work. Engine performance, combustion and exhaust emission characteristics were evaluated at two specific conditions. The first condition was an increase in engine speed from 1500 to 3500 rpm at partial engine load and the second condition involved maintaining a constant speed of 2500 rpm at three different engine loads (0.05, 0.4 and 0.7 MPa). Lower brake power was noticed when operating with B20 and B20 M5 blend. However, an increase in brake specific fuel consumption of 4–6% was observed when the engine was fuelled with B20 and B20 M5. The results indicate that NO_x emissions increase (up to 13%) while lower carbon monoxide and carbon dioxide (up to 17–18%) are observed in contrast with the mineral diesel.

14/02667 Effects of pilot fuel quantity on the emissions characteristics of a CNG/diesel dual fuel engine with optimized pilot injection timing

Liu, J. *et al. Applied Energy*, 2013, 110, 201–206.

For compressed natural gas (CNG)–diesel dual fuel engines, the effects of pilot fuel quantity and injection timing are noticeable and significant. In this study, the emission characteristics of a CNG–diesel dual fuel engine with different pilot diesel fuel quantity and optimized pilot injection timing were investigated. The CO emission levels under dual fuel mode are considerably higher than that under normal diesel operation modes even at high load, which indicated that there exist some flame extinction regions. Dual fuel mode reduces NO_x emissions by 30% averagely in comparison to diesel mode, that is because most of the fuel is burned under lean premixed conditions which result in lower local temperature. The unburned hydrocarbon emissions under dual-fuel mode are obviously higher than that of the normal diesel mode, especially at low to medium loads. And around 90% of the total hydrocarbon (THC) emissions were unburned methane, which means the flame does not propagate throughout the charge. THC emissions reduce significantly with the increase of the pilot diesel quantity.

Thanks to the premixed nature of the combustion mode and the methane molecular structure, the particulate matter (PM) emissions are significantly reduced under dual fuel conditions. The PM emissions are increased with the increase of the pilot fuel quantity.

14/02668 Energy efficiency analysis of a series plug-in hybrid electric bus with different energy management strategies and battery sizes

Hu, X. *et al. Applied Energy*, 2013, 111, 1001–1009.

This paper considers the tank-to-wheel (TTW) analysis of a plug-in hybrid electric bus operated in Gothenburg, Sweden. The bus line and the powertrain model are described. The definition and the calculation method of the recuperation and fuel-to-traction efficiencies are delineated for evaluating the TTW energy conversion. The two efficiencies are quantified and compared for two optimization-based energy management strategies, in which convex modelling and optimization are used. The impact of downsizing the battery on the two efficiencies is also investigated.

14/02669 Experimental study of dual fuel engine performance using variable LPG composition and engine parameters

Elnajjar, E. *et al. Energy Conversion and Management*, 2013, 76, 32–42.

The present work investigates experimentally the effect of liquefied petroleum gas (LPG) fuel with different composition and engine parameters on the performance of a dual compression engine. Five different blends of LPG fuels are used with propane to butane volume ratio of 100 : 0, 70 : 30, 55 : 45, 25 : 75 and 0 : 100. A single cylinder, naturally aspirated, four-stroke, indirectly injected, water cooled modified Ricardo E6 engine, is used in this study. The study is carried out by measuring the cylinder pressure, engine load, engine speed, crank angle and the fuel's flow rate. The engine performance under variable LPG fuel composition, engine load, pilot fuel injection timing, compression ratio, pilot fuel mass and engine speed, are estimated by comparing the following engine parameters: the cylinder maximum pressure, the indicated mean effective pressure, the maximum rate of pressure rise, and the thermal efficiency. The experimental data indicates that the engine parameters are playing a major role on the engine's performance. Different LPG fuel composition did not show a major effect on the engine efficiency but directly impacted the levels of generated combustion noise.

14/02670 High benefits approach for electrical energy conversion in electric vehicles from DC to PWM-AC without any generated harmonic

Fathabadi, H. *Energy Conversion and Management*, 2014, 77, 324–333.

This paper presents a novel hybrid power source, including a Li-ion battery together with an interface, which generates simultaneously electrical energy with the forms of both DC and AC for electric vehicles. A novel and high benefits approach is applied to convert the electrical energy of the Li-ion battery from DC form to single-phase symmetric pulse-width modulation (PWM)-AC form. Harmonic generation is one of the important problems when electrical energy is converted from DC to AC but there are not any generated harmonic during the DC/AC conversion using the proposed technique. The proposed system can be used in electric/hybrid vehicles because it has many benefits. Minimizing the energy loss (saving energy), no generated harmonic, the capability of arbitrary/necessary frequency selection for output AC voltage and the ability of long-distance energy transmission are some novelties and advantages of the proposed system. The proposed hybrid power source including DC/AC PWM inverter is simulated in the Proteus 6 software environment and a laboratory-based prototype of the hybrid power source is constructed to validate the theoretical and simulation results. Simulation and experimental results are presented to prove the superiority of the proposed hybrid power supply.

14/02671 Intelligent battery energy management and control for vehicle-to-grid via cloud computing network

Khayyam, H. *et al. Applied Energy*, 2013, 111, 971–981.

Plug-in electric vehicles (PEVs) provide new opportunities to reduce fuel consumption and exhaust emission. PEVs need to draw and store energy from an electrical grid to supply propulsive energy for the vehicle. As a result, it is important to know when PEVs batteries are available for charging and discharging. Furthermore, battery energy management and control is imperative for PEVs as the vehicle operation and even the safety of passengers depend on the battery system. Thus, scheduling the grid power electricity with parking lots would be needed for efficient charging and discharging of PEV batteries. This paper aims to propose a new intelligent battery energy management and control scheduling service charging that utilize cloud computing networks. The proposed intelligent vehicle-to-grid scheduling service offers the computational scalability required to make decisions necessary to allow PEVs battery energy management systems to operate efficiently when the number of PEVs and charging devices are large. Experimental analyses of the proposed scheduling service as compared to a traditional scheduling service are conducted through simulations. The results show that the proposed intelligent battery energy management scheduling service substantially reduces the required number of interactions of PEV with parking lots and grid as well as predicting the load demand calculated in advance with regards to their limitations. Also it shows that the intelligent scheduling service charging using cloud computing network is more efficient than the traditional scheduling service network for battery energy management and control.

14/02672 Intelligent optimization to integrate a plug-in hybrid electric vehicle smart parking lot with renewable energy resources and enhance grid characteristics

Fazelpour, F. *et al. Energy Conversion and Management*, 2014, 77, 250–261.

Widespread application of plug-in hybrid electric vehicles (PHEVs) as an important part of smart grids requires drivers and power grid constraints to be satisfied simultaneously. This study addresses these two challenges with the presence of renewable energy and charging rate optimization. First, optimal sizing and siting for installation of a distributed generation (DG) system is performed through the grid considering power loss minimization and voltage enhancement. Due to its benefits, the obtained optimum site is considered as the optimum location for constructing a cinema complex equipped with a PHEV parking lot. To satisfy the obtained size of distributed generation, an on-grid hybrid renewable energy system (HRES) is chosen. In the next set of optimizations, optimal sizing of the HRES is performed to minimize the energy cost and to find the best number of decision variables, which are the number of the system's components. Eventually, considering demand uncertainties due to the unpredictability of the arrival and departure times of the vehicles, time-dependent charging rate optimizations of the PHEVs are performed in 1 h intervals for the 24-h of a day. All optimization problems are performed using genetic algorithms. The outcome of the proposed optimization sets can be considered as design steps of an efficient grid-friendly parking lot of PHEVs. The results indicate a reduction in real power losses and improvement in the voltage profile through the distribution line. They also show the competence of the utilized energy delivery method in making intelligent time-dependent decisions in off-peak and on-peak times for smart parking lots.

14/02673 Large-scale deployment of electric vehicles in Germany by 2030: an analysis of grid-to-vehicle and vehicle-to-grid concepts

Loisel, R. *et al. Energy Policy*, 2014, 65, 432–443.

This study analyses battery electric vehicles (BEVs) in the future German power system and makes projections of the BEVs hourly load profile by car size ('mini', 'small', 'compact' and 'large'). By means of a power plant dispatching optimization model, the study assesses the optimal BEV charging/discharging strategies in grid-to-vehicle (G2V) and vehicle-to-grid (V2G) schemes. The results show that the 2% rise in power demand required to power these BEVs does not hamper system stability provided an optimal G2V scheme is applied. Moreover, such BEV deployment can contribute to further integrating wind and solar power generation. Applying a V2G scheme would increase the capacity factors of base and mid-load power plants, leading to a higher integration of intermittent renewables and resulting in a decrease in system costs. However, the evaluation of the profitability of BEVs shows that applying a V2G scheme is not a viable economic option due to the high cost of investing in batteries. Some BEV owners would make modest profits (€6 a year), but a higher number would sustain losses, for reasons of scale. For BEVs to become part of the power system, further incentives are necessary to make the business model attractive to car owners.

14/02674 Optimal decentralized valley-filling charging strategy for electric vehicles

Zhang, K. *et al. Energy Conversion and Management*, 2014, 78, 537–550.

The uncoordinated charging loads of electric vehicles (EVs) increases the peak load of the power grid, thereby increasing the cost of electricity generation. The valley-filling charging scenario offers a cheaper alternative. This study proposes a novel decentralized valley-filling charging strategy, in which a day-ahead pricing scheme is designed by solving a minimum-cost optimization problem. The pricing scheme can be broadcasted to EV owners, and the individual charging behaviours can be indirectly coordinated. EV owners respond to the pricing scheme by autonomously optimizing their individual charge patterns. This device-level response induces a valley-filling effect in the grid at the system level. The proposed strategy offers three advantages: coordination (by the valley-filling effect), practicality (no requirement for a bidirectional communication/control network between the grid and EV owners) and autonomy (user control of EV charge patterns). The proposed strategy is validated in simulations of typical scenarios in

Beijing, China. According to the results, the strategy (1) effectively achieves the valley-filling charging effect at 28% less generation cost than the uncoordinated charging strategy, (2) is robust to several potential affecters of the valley-filling effect, such as (system-level) inaccurate parameter estimation and (device-level) response capability and willingness (which cause less than 2% deviation in the minimal generation cost) and (3) is compatible with device-level multi-objective charging optimization algorithms.

14/02675 Optimal investment and scheduling of distributed energy resources with uncertainty in electric vehicle driving schedules

Cardoso, G. *et al. Energy*, 2014, 64, 17–30.

The large-scale penetration of electric vehicles (EVs) will introduce technical challenges to the distribution grid, but also carries the potential for vehicle-to-grid services. Namely, if available in large enough numbers, EVs can be used as a distributed energy resource (DER) and their presence can influence optimal DER investment and scheduling decisions in microgrids. In this work, a novel EV fleet aggregator model is introduced in a stochastic formulation of DER-CAM, an optimization tool used to address DER investment and scheduling problems. This is used to assess the impact of EV interconnections on optimal DER solutions considering uncertainty in EV driving schedules. Optimization results indicate that EVs can have a significant impact on DER investments, particularly if considering short payback periods. Furthermore, results suggest that uncertainty in driving schedules carries little significance to total energy costs, which is corroborated by results obtained using the stochastic formulation of the problem.

14/02676 Simulation tool for energy management of photovoltaic systems in electric vehicles

Tina, G. M. and Ventura, C. *Energy Conversion and Management*, 2014, 78, 851–861.

High autonomy is an important goal of most mobile systems. It can be achieved in three ways: reducing energy consumption, increasing the capacity of batteries and replenishing battery energy over time. Another possibility comes from using an on-board generating system: in this context an embedded photovoltaic system (PVS) is a feasible solution. To model the whole system and to evaluate its energy performance, a Simulink model in Matlab environment has been developed. Meteorological variables (radiance and ambient temperature) are essential inputs to estimate the power production of a PVS. In this simulator, measured, forecast as well as calculated values of radiation and temperature can be considered. Once the path followed by a mobile PVS (MPVS) is known, the Simulink tool calculates both the energy produced by PVS and the energy consumption. Different scenarios concerning the optimization of the PV production, considering the path followed by the MPVS, its consumption and the available solar radiation, have been considered and simulated. This model can become a useful tool to estimate the power production of PVS applied to any mobile system in such a way not only to optimize the energy performances but also to refine the sizing of the PVS. A mobile robot is used as test-bed.

14/02677 The impact on electricity demand and emissions due to the introduction of electric cars in the São Paulo power system

Dias, M. V. X. *et al. Energy Policy*, 2014, 65, 298–304.

The pursuit to find less-polluting energy sources has been on the increase. In general, the transportation sector is responsible for most of the emissions of greenhouse gases. Therefore, in this article, a methodological approach is applied in such a way that it is possible to quantify the impact of the penetration of electric vehicles *vis-à-vis* others that use different types of fuel (flexible fuel, for example). The study is conducted for a road model in São Paulo, the main state in Brazil in terms of economy, energy and environment, taking into account only automobiles. A comparative analysis of forecasting scenarios until 2035 for various inputs of electric cars in the whole state fleet is presented, aiming to verify the susceptibility of the model suggested, on the introduction of electric vehicles, taking into account also the electrical and environmental impacts related to it. The analysis was possible due to the use of a simulation tool, Long-range Energy Alternatives Planning System (LEAP), which is an energy environmental model based on scenarios, allowing an integrated and reliable support to develop studies on integrated energy planning.

14/02678 Towards improvement of natural gas-diesel dual fuel mode: an experimental investigation on performance and exhaust emissions

Lounici, M. S. *et al. Energy*, 2014, 64, 200–211.

The use of natural gas in compression ignition engines as supplement to liquid diesel in a dual fuel combustion mode is a promising technique. In this study, the effect of dual fuel operating mode on combustion characteristics, engine performances and pollutants emissions of an existing diesel engine using natural gas as primary fuel and neat diesel as pilot fuel, has been examined. At moderate and relatively high loads, the results show very interesting behaviour of dual fuel operating mode in comparison to conventional diesel, both for engine performance and emissions. It showed a simultaneous reduction of soot and NO_x species over a large engine operating area. Moreover, it showed the possibility to obtain lower brake-specific fuel consumption than conventional diesel engines. However, this mode presents some deficits at low loads, especially concerning unburned hydrocarbons and carbon monoxide emissions. Understanding these deficiencies is a key to improving such engines. Some suggestions for new measures towards dual fuel mode improvement are deduced.

Transport battery development

14/02679 A data-driven multi-scale extended Kalman filtering based parameter and state estimation approach of lithium-ion polymer battery in electric vehicles

Xiong, R. *et al. Applied Energy*, 2014, 113, 463–476.

Accurate estimations of battery parameter and state play an important role in promoting the commercialization of electric vehicles. This paper tries to make three contributions to the existing literature through an advanced time-scale separation algorithm. (1) A lumped parameter battery model was improved for achieving accurate voltage estimate against different battery aging levels through an electrochemical equation which has enhanced the relationship of battery voltage to its state-of-charge (SoC) and capacity. (2) A multi-scale extended Kalman filtering was proposed and employed to execute the online measured data driven-based battery parameter and SoC estimation with dual time scales with regarding to the slow-varying characteristic on the battery parameter and the fast-varying characteristic on the battery SoC, thus the battery parameter was estimated with macro-scale and battery SoC was estimated with micro-scale. (3) The accurate estimate of battery capacity and SoC were obtained in real-time through a data-driven multi-scale extended Kalman filtering algorithm. Experimental results on various degradation states of lithium-ion polymer battery cells further verified the feasibility of the proposed approach.

14/02680 A dynamic model-based estimate of the value of a vanadium redox flow battery for frequency regulation in Texas

Fares, R. L. *et al. Applied Energy*, 2014, 113, 189–198.

Building on past work seeking to value emerging energy storage technologies in grid-based applications, this paper introduces a dynamic model-based framework to value a vanadium redox flow battery (VRFB) participating in Texas' organized electricity market. The model describes the dynamic behaviour of a VRFB system's voltage and state of charge based on the instantaneous charging or discharging power required from the battery. The authors formulate an optimization problem that incorporates the model to show the potential value of a VRFB used for frequency regulation service in Texas. The optimization is implemented in Matlab using the large-scale, interior-point, non-linear optimization algorithm, with the objective function gradient, non-linear constraint gradients, and Hessian matrix specified analytically. Utilizing market prices and other relevant data from the Electric Reliability Council of Texas (ERCOT), it was found that a VRFB system used for frequency regulation service could be worth approximately $1500/kW.

14/02681 Capacity fade and aging models for electric batteries and optimal charging strategy for electric vehicles

Fernández, I. J. *et al. Energy*, 2013, 60, 35–43.

Due to the increasing concern for energy efficient storage devices, extensive research is being done on the mechanisms which are involved in the battery degradation process. Optimality in electric vehicle energy management has been traditionally pursued from the perspective of efficient grid operation, but barely considering battery degradation in the process. The objective is to formulate a battery degradation model which will yield the degradation suffered by a battery as a function of its use, allowing both the comparison between different energy management strategies as well as including the model in linear optimization algorithms. Nearly 300 tests were carried out on Li-ion battery cells which were subjected to different depth-of discharges, currents and temperatures. Results are used to identify the variables which categorize best, using self-organizing maps, the degradation suffered by the cells. A model is proposed which yields the rate of degradation of the battery as a function of both temperature and depth-of-discharge. This model is then linearized and used in an electric vehicle energy management optimization problem, where the degradation suffered by the battery due to a controlled charge is minimized. Finally, the results are compared with other charging methods.

14/02682 Computational studies on the effect of geometric parameters on the performance of a solar chimney power plant

Patel, S. K. *et al. Energy Conversion and Management*, 2014, 77, 424–431.

A solar chimney power plant (SCPP) is a renewable energy power plant that transforms solar energy into electricity. The SCPP consists of three essential elements: solar air collector, chimney tower and wind turbine(s). The present work aims to optimize the geometry of the major components of the SCPP using a computational fluid dynamics software ANSYS-CFX to study and improve the flow characteristics inside the SCPP. The overall chimney height and the collector diameter of the SCPP were kept constant at 10 and 8 m respectively. The collector inlet opening was varied from 0.05 to 0.2 m. The collector outlet diameter was also varied from 0.6 to 1.0 m. These modified collectors were tested with chimneys of different divergence angles (0°–3°) and also different chimney inlet openings of 0.6 to 1.0 m. The diameter of the chimney was also varied from 0.25 to 0.3 m. Based on the CFX computational results, the best configuration was achieved using the chimney with a divergence angle of 2° and chimney diameter of 0.25 m together with the collector opening of 0.05 m and collector outlet diameter of 1.0tsp;m. The temperature inside the collector is higher for the lower opening resulting in a higher flow rate and power.

14/02683 Electrochemical performance of $LiCoO_2$/ $SrLi_2Ti_6O_{14}$ batteries for high-power applications

Liu, J. *et al. Journal of Power Sources*, 2014, 245, 371–376.

$LiCoO_2/SrLi_2Ti_6O_{14}$ Li-ion rechargeable batteries with ~6 Ah capacities are designed and assembled for use in hybrid electric vehicle (HEV) applications. For comparison, $LiCoO_2/Li_4Ti_5O_{12}$ batteries are also constructed using similar processing parameters. Power tests are carried out using the hybrid pulse power characterization (HPPC) method. Experimental results show that the $LiCoO_2/SrLi_2Ti_6O_{14}$ batteries have better power performance and more stable charge/discharge direct current (DC) resistances compared with the $LiCoO_2/Li_4Ti_5O_{12}$ batteries. At a 50% depth of discharge (DOD), $LiCoO_2/SrLi_2Ti_6O_{14}$ batteries have an excellent specific charge power density of 3973 W kg^{-1}, which can be attributed to the high Li diffusion capability and high electronic conductivity of the $SrLi_2Ti_6O_{14}$ material.

14/02684 Energy management strategy for plug-in hybrid electric vehicles. A comparative study

Torres, J. L. *et al. Applied Energy*, 2014, 113, 816–824.

This paper presents the development of an energy management strategy of a plug-in hybrid electric vehicle. In this case, a rule-based optimal controller selects the appropriate operation mode. Furthermore, advantages and drawbacks of such vehicles are compared with respect to other vehicles powered by the most popular powertrain architectures. Simulations are carried out for three predefined drive cycles repeated over different geographic regions with varying CO_2 intensities. The results reveal that the proposed controller is able to switch the vehicle's operating mode according to previous established criteria.

14/02685 Enhanced sample entropy-based health management of Li-ion battery for electrified vehicles

Hu, X. *et al. Energy*, 2014, 64, 953–960.

This paper discusses an ameliorated sample entropy-based capacity estimator for prognostics and health management of Li-ion batteries in electrified vehicles. The aging datasets of eight cells with identical chemistry were used. The sample entropy of cell voltage sequence under the well-known hybrid pulse power characterization profile is adopted as the input of the health estimator. The calculated sample entropy and capacity of a reference Li-ion cell (randomly selected from the eight cells) at three different ambient temperatures are employed as the training data to establish the model by using the least-squares optimization. The performance and robustness of the estimator are validated by means of the degradation datasets from the other seven cells. The associated results indicate that the proposed health management strategy has an average relative error of about 2%.

14/02686 Evaluating the impact of V2G services on the degradation of batteries in PHEV and EV

Bishop, J. D. K. *et al. Applied Energy*, 2013, 111, 206–218.

Many researchers and industry observers claim that electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) could provide vehicle-to-grid (V2G) bulk energy and ancillary services to an electricity network. This work quantified the impact on various battery characteristics whilst providing such services. The sensitivity of the impact of V2G services on battery degradation was assessed for EV and PHEV for different battery capacities, charging regimes, and battery depth of discharge. Battery degradation was found to be most dependent on energy throughput for both the EV and PHEV powertrains, but was most sensitive to charging regime (for EVs) and battery capacity (for PHEVs). When providing ancillary services, battery degradation in both powertrains was most sensitive to individual vehicle battery depth of discharge. Degradation arising from both bulk energy and ancillary services could be minimized by reducing the battery capacity of the vehicle, restricting the number of hours connected and reducing the depth of discharge of each vehicle for ancillary services. Regardless, best case minimum impacts of providing V2G services are severe such as to require multiple battery pack replacements over the vehicle lifetime.

14/02687 Graphical and mathematical analysis of fuel cell/battery passive hybridization with K factors

Lee, S. C. *et al. Applied Energy*, 2014, 114, 135–145.

Hybridization is a promising method for enhancing the quality of the power-supply system including fuel cells which is not capable of meeting load demand statically or dynamically. Although there have been many research advances on hybridization, systematic studies are found to be insufficient in revealing the fundamental characteristics. This study systematically categorizes passive hybrid topologies, which are battery state-of-charge controlled, fuel cell relative humidity controlled, and battery–fuel cell controlled, respectively. Each hybrid topology can be analysed based on the graphical and mathematical method for fundamentally understanding and designing the hybrid system. First, in the graphical method, I–V curves, which represent the characteristics of the intrinsic properties of each device, are used to understand the current sharing and power sharing of the hybrid system. Second, the mathematical method based on the relations deduced from each characterization curve is used for a more detailed understanding on topology to find the key factors of hybridization. The results show that the power sharing of hybridization is strongly connected to the fundamental properties of each device, and it can be expressed by a combination of two factors K_V and K_R, which represent the electrical potential and internal resistance ratio of each device, respectively.

14/02688 Integrated modeling for the cyclic behavior of high power Li-ion batteries under extended operating conditions

Miranda, Á. G. and Hong, C. W. *Applied Energy*, 2013, 111, 681–689.

The dynamic thermal and electrical behaviour of high power $LiFePO_4$ cathode-type Li-ion batteries is studied with extended considerations such as demanded current ranging from 12 to 30 A, battery temperatures ranging from 283 to 313 K and a redefinition of the concept of state of charge during cycling conditions. The equivalent electrical model, consisting of a series resistance, a parallel resistance–capacitor, a voltage source and state of charge calculators, can be improved with the addition of current and temperature gains for each element. In addition, a non-intrusively-obtained alternative thermal model extraction is proposed to uncouple from the experimental battery temperature based on electrochemical research found in the literature. This improved model extraction for high power cylindrical batteries can achieve a temperature and voltage relative runtime error in the range of 1% and 5% in average, respectively. The effects of lithium concentration in the anode and cathode are accurately predicted with state of charge accelerators, which vary linearly with temperature. Aiming for a power systems environment, the integrated battery model is built and validated experimentally to demonstrate its accurate prediction. This improved integrated battery model can be employed for battery stack simulations, improved state of charge algorithm testing and optimization of hybrid systems – with a light computational demand. Finally, a performance index radar plot is proposed to conveniently compare electrical and thermal properties of different types of batteries.

14/02689 State of charge estimation of lithium-ion batteries using the open-circuit voltage at various ambient temperatures

Xing, Y. *et al. Applied Energy*, 2014, 113, 106–115.

Ambient temperature is a significant factor that influences the accuracy of battery state-of-charge (SOC) estimation, which is critical for remaining driving range prediction of electric vehicles (EVs) and optimal charge/discharge control of batteries. A widely used method to estimate SOC is based on an online inference of open-circuit voltage (OCV). However, the fact that the OCV–SOC is dependent on ambient temperature can result in errors in battery SOC estimation. To address this problem, this paper presents an SOC estimation approach based on a temperature-based model incorporated with an OCV–SOC–temperature table. The unscented Kalman filtering (UKF) was applied to tune the model parameters at each sampling step to cope with various uncertainties arising from the operation environment, cell-to-cell variation, and modelling inaccuracy. Two dynamic tests, the dynamic stress test (DST) and the federal urban driving schedule (FUDS), were used to test batteries at different temperatures. Then, DST was used to identify the model parameters while FUDS was used to validate the performance of the SOC estimation. The estimation was made covering the major working range from 25% to 85% SOC. The results indicated that this method can provide accurate SOC estimation with smaller root-mean-squared errors than the method that does not take into account ambient temperature. Thus, the approach is effective and accurate when battery operates at different ambient temperatures. Since the developed method takes into account the temperature factor as well as the complexity of the model, it could be effectively applied in battery management systems for EVs.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

14/02690 Adsorption applications of unmodified geothermal silica

Svavarsson, H. G. *et al. Geothermics*, 2014, 50, 30–34.

Silica, precipitated out of geothermal fluid discharged from a geothermal power plant in Svartsengi on the Reykjanes peninsula in Iceland, was used as a chromatographic adsorbent to extract blue-coloured protein, C-phycocyanin, from *coccoid* blue-green algae. The only supplement used was salt obtained by evaporating the geothermal fluid. Analysis of the silica, using scanning electron microscopy, X-ray diffractometry and Brunauer–Emmett–Teller adsorption confirmed it has a high specific surface area and is amorphous. On adsorption and subsequent elution the purity of the extracted protein, measured as the ratio of the light absorbance of 620 and 280 nm, increased from 0.5 to above 2.0. The results could facilitate utilization of a mostly unused by-product of geothermal power plants as chromatographic material.

14/02691 Amines immobilized double-walled silica nanotubes for CO_2 capture

Ko, Y. G. *et al. Journal of Hazardous Materials*, 2013, 250–251, 53–60.

Novel silica support has been required for high amine loading and good CO_2 molecule diffusion into its pores to increase the performance of CO_2 adsorbents. Herein, amine groups supported on double-walled silica nanotubes (DWSNTs) have been prepared via the immobilization of various aminosilanes (primary, secondary, tertiary, di-, and tri-aminosilanes) on DWSNT, and found to be a very effective adsorbent for CO_2 capture. Amine groups immobilized DWSNTs captured CO_2 reversibly in a temperature swing process at various adsorption temperatures (25, 50, 75 and 100 °C). The amines on modified DWSNTs showed high CO_2 capture capacity in the order of tri-, di-, primary, secondary, and tertiary amines. The CO_2 capture capacity of all aminosilanes immobilized DWSNTs decreased linearly with the increase of the adsorption temperature. It is hoped that DWSNT would be able to inspire researchers to use it not only as a support for CO_2 capture but also as a promising candidate for various applications.

14/02692 Cellulose templating method for the preparation of $La_{0.8}Sr_{0.2}Ga_{0.83}Mg_{0.17}O_{2.815}$ (LSGM) solid oxide electrolyte

Sariboğa, V. *et al. Journal of the European Ceramic Society*, 2013, 33, (8), 1435–1446.

$La_{0.8}Sr_{0.2}Ga_{0.83}Mg_{0.17}O_{2.815}$ (LSGM) materials are synthesized with a fast and facile cellulose templating method for the first time and characterized by X-ray diffraction, electrochemical impedance spectroscopy, Archimedes method and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM–EDS). LSGM powders with a phase purity of 91.7 mol% are obtained after the calcination at 1300 °C for 12 h. SEM–EDS results indicate possible decomposition and reconstruction of the LSGM phase due to the diffusion of Sr-rich species to the grain boundaries for the sample sintered at 1500 °C for 6 h. Maximum conductivity value is found to be $4.2 \times 10^{-2}\,\mathrm{S\,cm^{-1}}$ at 800 °C for the sample calcined at 1300 °C for 12 h and sintered at 1400 °C for 6 h. Phase purity, stability and relative density are the important factors for obtaining high performance LSGM electrolytes. Therefore, cellulose templating method is a promising candidate for the preparation of LSGM electrolytes.

14/02693 Densification and properties of bulk nanocrystalline functional ceramics with grain size below 50 nm

Maglia, F. *et al. Journal of the European Ceramic Society*, 2013, 33, (6), 1045–1066.

The synthesis and functional characterization of dense bulk nanometric oxides are reviewed, with particular emphasis on the modifications that a grain size in the low nanometric range (10–50 nm) introduces in their physical properties. The preparation of ceramics with low porosity and extremely small grain size is particularly challenging and mostly relies on the sintering of extremely fine nanopowder. The most popular methods for the preparation of the starting nanopowders are introduced and briefly discussed as well as the most widely employed densification techniques. The role of nanostructure in controlling phase stability, electrical and thermal transport, optical and magnetic properties of nano-oxides is discussed in details. Several examples are given where bulk materials prepared with grain size equal or below 50 nm show characteristics that are either enhanced or, in some cases, completely different from those possessed by the same materials, but with larger grain sizes.

14/02694 Development and sensitivity study of a simplified and dynamic method for double glazing facade and verified by a full-scale façade element

Liu, M. *et al. Energy and Buildings*, 2014, 68, 432–443.

The research aims to develop a simplified calculation method for double glazing facade to calculate its thermal and solar properties (U and g values) together with comfort performance (internal surface temperature of the glazing). Double glazing is defined as one-dimensional model with nodes representing different layers of material. Several models with different numbers of nodes or in different positions are compared and verified in order to find a simplified method which can calculate the performance as accurately as possible. The performance calculated in terms of internal surface temperature is verified with experimental data collected in a full-scale facade element test facility at Aalborg University in Denmark. Comparison was conducted between the simplified method and WIS software on the accuracy of calculating internal surface temperature of double-glazing facade. The method is based on standards EN410 and EN673, taking the thermal mass of the glazing into account. In addition, angle and spectral dependency of solar characteristic is also considered during the calculation. By using the method, it is possible to calculate whole-year performance at different time steps, which makes it a time economical and accurate tool in design stage of double-glazing facade.

14/02695 Development of a new clay supported polyethylenimine composite for CO_2 capture

Wang, W. *et al. Applied Energy*, 2014, 113, 334–341.

A new inexpensive inorganic–organic composite sorbent for CO_2 capture was prepared by the immobilization of a branched polyethyleneimine (PEI) onto porosity-enhanced clays using the wet impregnation method. In the composite, a low cost and naturally abundant clays (e.g. kaolinite and montmorillonite) was used as the supporting material, which was pre-modified by acid- or alkaline-treatment to improve its textural properties, i.e. pore volume and surface area, for accommodating the CO_2-philic PEI. Among the modified clays, the montmorillonite modified by 6 M HCl (Mon_HCl_6M) showed the highest porosity with the pore volume of 0.71 from 0.16 $\mathrm{cm^3/g}$, and BET surface area of 253 from 72 $\mathrm{m^2/g}$. The cost of the Mon_HCl_6M was estimated as $0.14/kg, which was significantly lower than reported supporting materials for the amine-based sorbents for CO_2 capture. At the optimal PEI loading of 50 wt% on the Mon_HCl_6M support, the CO_2 sorption capacity reached 112 mg CO_2/g-sorbent at 75 °C under dry condition, which can be further enhanced to 142 mg CO_2/g-sorbent with the moisture addition (*ca.* 3 vol%) due to the change in the interaction mechanism between CO_2 and amine in the presence of moisture. Moreover, the PEI/Mon_HCl_6M sorbent showed a good regenerability for 10 sorption–desorption cycles tested and a good thermal stability in the temperature range of CO_2 sorption (75 °C) and desorption (100 °C).

14/02696 Electrochemical study of lithiated transition metal oxide composite as symmetrical electrode for low temperature ceramic fuel cells

Fan, L. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11398–11405.

In this work, lithiated $NiCuZnO_x$ (LNCZO) composite is synthesized and evaluated as a potential symmetrical electrode for ceria-carbonate composite electrolyte-based low-temperature ceramic fuel cells. Its crystal structures, the hydrogen oxidation/oxygen reduction electrochemical activities and fuel cell performances are systematically examined on the symmetrical cell configuration. Nano-crystallite particles in the form of composite are observed for these oxides. The LNCZO shows relatively high catalytic activities for hydrogen oxidation and oxygen reduction reaction according to the electrochemical impedance spectroscopy measurements. A remarkable low oxygen reduction activation energy of 42 kJ mol^{-1} is obtained on the LNCZO/ceria-carbonate composite, demonstrating excellent electro-catalytic activity. Especially, the catalytic activity can be further improved in the presence of water in the cathode chamber. The results show that the lithiated transition metal oxide composite is a promising symmetrical electrode for ceria-carbonate electrolyte and composite approach might a probable solution to develop super-performance electrodes for reduced temperature ceramic fuel cells.

14/02697 Encapsulation of TRISO particle fuel in durable soda-lime-silicate glasses

Heath, P. G. *et al. Journal of Nuclear Materials*, 2013, 436, (1–3), 139–149.

Tri-structural isotropic (TRISO) coated particle-fuel is a key component in designs for future high-temperature nuclear reactors. This study investigated the suitability of three soda lime silicate glass compositions, for the encapsulation of simulant TRISO particle fuel. A cold press and sinter (CPS) methodology was employed to produce TRISO particle–glass composites. Composites produced were determined to have an aqueous durability, fracture toughness and Vickers' hardness comparable to glasses currently employed for the disposal of high level nuclear wastes. Sintering at 700 °C for 30 min was found to remove all interconnected porosity from the composite bodies and oxidation of the outer pyrolytic carbon layer during sintering was prevented by processing under a 5% H_2/N_2 atmosphere. However, the outer pyrolytic carbon layer was not effectively wetted by the encapsulating glass matrix. The aqueous durability of the TRISO particle–glass composites was investigated using PCT and MCC-1 tests combined with geochemical modelling. It was found that durability was dependent on silicate and calcium solution saturation. This study provides significant advancements in the preparation of TRISO particle encapsulant waste forms. The potential for the use of non-borosilicate sintered glass composites for TRISO particle encapsulation has been confirmed, although further refinements are required.

14/02698 Flow resistance for different types of windows in the case of buoyancy ventilation

von Grabe, J. *Energy and Buildings*, 2013, 65, 516–522.

In a previous paper, the authors have quantified the buoyancy-driven mass flow rates for different types of windows that result from a temperature difference of 1 K between the two spaces that are separated by the window in question. For the examined windows it was possible to relate the opening rate to the resulting mass flow by a logarithmic function. This paper draws on these results and shows how to further develop them to basic flow parameters and thus to generalize the outcomes to arbitrary situations. The most important flow parameter in this context is the flow resistance ζ of the window opening. This flow resistance is quantified for the examined window types and the results show that the flow resistances are virtually identical for the majority of the tested window openings. In addition, the flow resistance is linearly and positively dependent on the size of the window opening. With these results, mass flow rates can easily be calculated for windows under buoyancy ventilation in thermal building simulations.

14/02699 High temperature collecting performance of a new all-glass evacuated tubular solar air heater with U-shaped tube heat exchanger

Wang, P.-Y. *et al. Energy Conversion and Management*, 2014, 77, 315–323.

An experimental and simulation study was conducted on a new-type all-glass evacuated tubular solar air heater with simplified compound parabolic concentrator (CPC). The system is made up of 10 linked collecting panels and each panel includes a simplified CPC and an all-glass evacuated tube with a U-shaped copper tube heat exchanger installed inside. Air is gradually heated when passing through each U-shaped copper tube. The heat transfer model of the solar air heater is established and the outlet air temperature, the heat power and heat efficiency are calculated. Calculated and experimental results show that the present experimental system can provide heated air with a temperature exceeding 200 °C. The whole system has an outstanding high-temperature collecting performance and the present heat transfer model can meet the general requirements of engineering calculations.

14/02700 Holographic lenses for building integrated concentrating photovoltaics

Chemisana, D. *et al. Applied Energy*, 2013, 110, 227–235.

A volume transmission phase holographic element was designed and constructed to perform as a building integrated photovoltaic (PV) concentrator. The holographic lens diffracts light in the spectral bandwidth to which the cell presents the highest sensitivity with a concentration factor of 3.6 times. In this way, the cell is protected from overheating because the infrared, for which the solar cell is not sensitive, is not concentrated. In addition, based on the asymmetric angular selectivity of the volume hologram and based on the linear concentration, only single-axis tracking is needed. The use of the holographic element increases the efficiency of the PV cell by 3% and the fill factor by 8%.

14/02701 Mechanical and thermal characterization of a ceramic/glass composite seal for solid oxide fuel cells

Dev, B. *et al. Journal of Power Sources*, 2014, 245, 958–966.

Solid oxide fuel cells (SOFCs) require seals that can function in harsh, elevated temperature environments. Comprehensive characterization and understanding of seals is needed for commercially viable SOFCs. The present research focuses on a novel ceramic/glass composite seal that is produced by roller compaction or tape casting of glass and ceramic powders and an organic binder. Upon heat treatment, micro-voids and surface anomalies are formed. Increased heating and cooling rates during the heat treatment resulted in more and larger voids. The first goal of the current research is to suggest an appropriate heating and cooling rate to minimize the formation of microstructural defects. After identifying an appropriate cure cycle, seals were thermally cycled and then characterized with laser dilatometry, X-ray diffraction, and sonic resonance. From these experiments the crystalline phases, thermal expansion, and elastic properties were determined. Subsequently compression testing with an acoustic emission sensor and post-test microstructural analysis were used to identify the formation of damage. By fully understanding the characteristics of this ceramic/glass composite seal, next generation seals can be fabricated for improved performance.

14/02702 Mirror symmetrical dielectric totally internally reflecting concentrator for building integrated photovoltaic systems

Muhammad-Sukki, F. *et al. Applied Energy*, 2014, 113, 32–40.

This paper describes a novel type of solar concentrator: a mirror symmetrical dielectric totally internally reflecting concentrator (MSDTIRC). This new concentrator type has been designed to satisfy the following objectives: (i) to provide optimum gain in two different planes, therefore increasing the electrical output of a solar photovoltaic (PV) system, and (ii) to reduce the amount of the PV cell material needed, hence minimizing the cost of the system. The concentrator is capable of having two different acceptance angles on different planes. The procedure of designing an MSDTIRC is explained and the geometrical properties are analysed in detail. In addition, the optical concentration gain is presented for various angles of incidence. Through simulation results, it is demonstrated that the MSDTIRC provides significant optical concentration gain within its acceptance angle, as high as 13.54× when compared with non-concentrating solar cell. It can be concluded that the MSDTIRC can be a way to produce a low-cost solar PV system and can be chosen as an alternative design for the building-integrated photovoltaics systems.

14/02703 N–Mo-borosilicate glass–ceramic: synthesis, characterization and response to ionizing radiation

Kossoy, A. *et al. Journal of Nuclear Materials*, 2013, 437, (1–3), 216–221.

A new borosilicate glass–ceramic with high content of Mo and Nd was synthesized and thoroughly characterized. The structure of the material after it was subjected to 5 MeV He^+ was investigated. 5 MeV He^+ was chosen since it deposits most of the energy as ionizing radiation rather than as nuclear stopping and therefore can be used to simulate self-radiation in advanced nuclear waste forms. As a result of irradiation, slight Mo reduction occurred together with increased numbers of crystalline precipitates. Those results are interesting for understanding the behaviour of systems with high Mo and Nd content such as nuclear waste forms demonstrating an influence that ionizing radiation can have on the chemistry, environmental stability and microstructure of the waste forms.

14/02704 Pd–Ni–Cu–P metallic glass nanowires for methanol and ethanol oxidation in alkaline media

Sekol, R. C. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11248–11255.

This study demonstrates that $Pd_{43}Ni_{10}Cu_{27}P_{20}$ bulk metallic glass (BMG) nanowires, prepared by a facile, scalable top-down nanomoulding approach, can be used as high surface area electrocatalysts for alkaline alcohol fuel cell applications. These nanowires exhibit higher activity for methanol and ethanol oxidation in alkaline media compared to pure Pd, quantified by cyclic voltammetry. Furthermore, the Pd-BMG nanowire electrocatalyst has a 300 mV lower onset potential for CO oxidation suggesting improved poisoning resistance beyond pure Pd. The Pd-BMG electrocatalyst activation energies for methanol and ethanol oxidation of 22 and 17 kJ mol^{-1} are lower than the pure Pd values of 38 and 30 kJ mol^{-1}, respectively. Unique properties of BMGs (homogeneity, viscosity, surface tension) facilitate the formability into high surface area electrocatalysts at low processing temperatures. The high electrical conductivity and chemical/physical stability suggest that these materials are ideal candidates for widespread commercial use including energy conversion/storage, hydrogen production, and sensors.

14/02705 Potential application of glazed transpired collectors to space heating in cold climates

Gao, L. *et al. Energy Conversion and Management*, 2014, 77, 690–699.
Although unglazed transpired collectors (UTC) succeed in industrial ventilation applications, the solar fraction is very low when they are used in space heating in cold climates due to the lower exit air temperature. Considering the potential for glazed transpired collectors (GTC) using recirculated air for space heating applications in cold climates, a mathematical model is developed for predicting the thermal performance of GTC. Simulation results show that although glazing results in optical loss, it could decrease convective heat loss resulted from high crosswind velocities effectively. For a solar radiation of $400\,W/m^2$, an ambient temperature of $-10\,°C$, and a suction velocity of 0.01 m/s, the exit air temperature of GTC is higher than that of UTC for crosswind velocities exceeding 3.0 m/s. By comparison with a conventional flat-plate solar air collector operating under the same conditions, the thermal performance of GTC shows a significant improvement. For a five-storey hotel building located in the severe cold climate zone of China, case study shows that the annual solar fraction of the GTC-based solar air heating system is about 20%, which is two times higher than that of the flat-plate collector-based system and nearly nine times higher than that of the UTC-based system respectively. Hence, an enormous amount of energy will be saved with the application of GTC to space heating in cold climates.

14/02706 Preparation of high-performance $Ca_3Co_4O_9$ thermoelectric ceramics produced by a new two-step method

Madre, M. A. *et al. Journal of the European Ceramic Society*, 2013, 33, (10), 1747–1754.
A high-performance $Ca_3Co_4O_9$ thermoelectric ceramic has been prepared from a $Ca_{1-x}Co_xO/Ca_yCo_{1-y}O$ divorced eutectic structure produced by a directional melt-grown using the laser floating zone technique. This material has been grown at very high solidification rate in order to produce a very fine microstructure to reduce the necessary annealing time to recover the $Ca_3Co_4O_9$ thermoelectric phase as the major one. As-grown and annealed samples were microstructurally characterized to determine the phases and estimate the extent of $Ca_3Co_4O_9$ formation with time and related with their thermoelectric performances. The optimum annealing time, 72 h, has been determined by the maximum power factor value (about $0.42\,mW\,K^{-2}\,m^{-1}$), which is around the best values reported in textured materials ($\sim 0.40\,mW\,K^{-2}\,m^{-1}$). This high power factor outcome from the high $Ca_3Co_4O_9$ phase content, apparent density and Co^{3+}/Co^{4+} relationship determinations performed in the present work.

14/02707 Pyrolytic and kinetic characteristics of waste glass substrate from liquid crystal display panels

Wang, X. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 100, 137–144.
The pyrolysis of waste glass substrate from liquid crystal display (LCD) was first investigated with the intention of treating hazardous LCD waste and recovering valuable resources. In order to obtain the information of thermal behaviour, a thermogravimetric (TG) and TG kinetic analysis of waste glass substrate was performed. According to the TG results, the pyrolysis experiments were carried out in the temperature range of 350–550 °C in a fixed bed reactor and the highest yield of liquid product was obtained at the final pyrolysis temperature of 450 °C. The compositions and characteristics of gaseous and liquid products were analysed using gas chromatography and gas chromatography–mass spectrometry complemented with elemental analysis, water content, high heating values and simulated distillations. Scanning electron microscopy and energy-dispersive X-ray spectroscopy were applied to analyse the solid product. The gaseous product was mainly comprised of H_2, CO, CO_2, CH_4 and a small amount of C_2 hydrocarbons (C_2H_6 and C_2H_2) which can be used as valuable fuel. The composition of liquid product was categorized into acids, esters, alcohols, ketones, aromatics, sugars and siloxanes with acids occupying the most proportion. The characteristic analysis indicated that the liquid product was high oxygen content and needed to be upgraded such as hydrotreating process before using as industrial feedstock or fuel source.

14/02708 Relation between piezoelectric properties of ceramics and output power density of energy harvester

Choi, C.-H. *et al. Journal of the European Ceramic Society*, 2013, 33, (7), 1343–1347.
Ceramics with formula $(1-x)Pb(Zr_{0.47}Ti_{0.53})O_3–xPb[(Zn_{0.4}Ni_{0.6})_{1/3}Nb_{2/3}]O_3$ $[(1-x)PZT–xP(ZN)N]$ where $0.26 \leq x \leq 0.31$, were sintered at 1100 °C, and their energy harvesters were fabricated. All specimens exhibit a similar energy convergence efficiency. However, the transduction coefficient ($d_{33} \times g_{33}$) increased with x, reaching $21.5 \times 10^{-15}\,m^2/N$ for the $x = 0.31$ specimen; the figure-of-merit of the specimens shows a similar variation. The output energy density of the energy harvester also increased with x, and a high output energy density of $231\,mW/cm^3$ was obtained for the harvester fabricated using the $x = 0.31$ specimen, indicating that the $d_{33} \times g_{33}$ value significantly affects the output energy density of the energy harvester.

14/02709 Semi-transparent PV windows: a study for office buildings in Brazil

Didoné, E. L. and Wagner, A. *Energy and Buildings*, 2013, 67, 136–142.
This research aims to develop a methodology for the evaluation of the potential energy saving and energy generation of semi-transparent photovoltaic (PV) windows in Brazilian office buildings. The evaluation is based on computer simulations: a daylighting simulation for the investigation of the available annual daylight with different window systems using Daysim/Radiance program and the simulation of the energetic performance using the program EnergyPlus. The simulations were accomplished for two cities in two different climatic zones of Brazil and compared to a German city. The results show that it is possible to reduce the energy consumption for artificial lighting and air-conditioning using appropriate control systems and furthermore to generate energy using semi-transparent PV panels in windows. Although only one building geometry was analysed, the results suggest that the potential of this technology is high in Brazil.

14/02710 Simulation of smart windows in the $ZnO/VO_2/ZnS$ sandwiched structure with improved thermochromic properties

Zhao, Y. *et al. Energy and Buildings*, 2013, 66, 545–552.
The authors modelled a sandwiched structure $ZnO/VO_2/ZnS$ potentially as a VO_2-based smart window with a goal to increase both luminous transmittance (T_{lum}) and solar modulation ability (ΔT_{sol}). Compared to the previously used single-layer antireflection coating, the new sandwiched structure broadens the reflectance minimum in the visible light range and enlarges the transmission gap in the near-infrared region, when switching between the semiconducting and the metallic states and when utilizing an intermediate index ZnS layer embedded between the VO_2 film and substrate. The $\frac{3}{4}-\frac{1}{4}-\frac{3}{4}$ wavelength–thickness model exhibited a high solar modulation ability ($\Delta T_{sol} =$ 13.01%), and maintained a high T_{lum} at 63.24% and 57.39% both in semiconducting and metallic phases, respectively.

14/02711 Structure and electrical properties of $0.85(Bi_{0.5}Na_{0.5})TiO_3–0.12BaTiO_3–0.03SrTiO_3$ ferroelectric ceramics

Mgbemere, H. E. *et al. Journal of the European Ceramic Society*, 2013, 33, (15–16), 3015–3022.
The crystal structure, domain structure and the electrical properties of $0.85(Bi_{0.5}Na_{0.5})TiO_3–0.12BaTiO_3–0.03SrTiO_3$ ceramics have been investigated. Rietveld refinement with Fullprof software was used to analyse the X-ray diffraction data and a two-phase coexistence between a monoclinic (*Cm*) phase and a tetragonal phase (*P4mm*) best describes the diffraction patterns from 25 to 100 °C. Results from X-ray diffraction and dielectric measurements show that the Curie temperature is between 220 and 240 °C. The domain structure shows the presence of both non-180° domain walls and 180° domain walls similar to that already observed in $Pb(Zr_xT_{1-x})O_3$ ceramics. The hysteresis curves show that the coercive field decreases with increasing temperature up to 100 °C. The piezoelectric charge coefficient (d^*_{33}) at 25 °C is $167 \pm 25\,pm/V$ and increased only slightly with temperature up to 100 °C. These properties make this piezoelectric ceramic material suitable for ultrasonic transducers, sonars, hydrophones and other applications.

14/02712 Study on combined heat loss of a dish receiver with quartz glass cover

Cui, F. *et al. Applied Energy*, 2013, 112, 690–696.
In this study, a cavity receiver with quartz glass cover is presented for the dish concentrating system. The quartz glass cover can separate the receiver cavity from the ambient air and its selective coating layer can intercept the infrared radiation emitted from the inner-surface of the cavity receiver, which greatly reduce the natural convection and surface radiation heat losses. To fundamentally understand this design, a two-dimensional model for the heat transfer process that combines the natural convection and the surface radiation is proposed and developed. The simulation results show that the total heat flux of the covered receiver at 0° inclination is only about 36% of that for uncovered receiver. The model is then used to investigate the effects of various system parameters, such as orientation, temperature and emissivity of inner surface, on the heat transfer and fluid flow performance. It is found that, comparing with the natural convection, the surface radiation is the dominant heat transfer pattern. The orientation has significantly influence the convection heat transfer. However, the surface radiation keeps constant for different inclination

angles. In addition, it is also found that the radiation heat transfer is significantly affected by the temperature and emissivity of the inner surface. The increase in the surface temperature and emissivity enhances the surface radiation proportion in the total heat loss. However, for the convection heat loss, it changes little and even decreases as the surface temperature and emissivity increases.

14/02713 Thermo-fluid dynamic modeling and simulation of a bioclimatic solar greenhouse with self-cleaning and photovoltaic glasses

Sdringola, P. *et al. Energy and Buildings*, 2014, 68, 183–195.

This paper describes Solaria, a multifunctional complex, developed in an unused industrial area located in a urban district in the immediate outskirts of Perugia, Italy. The complex was conceived and designed according to the principles of sustainable buildings. Energy efficiency solutions and innovative experimental components are synergically integrated in a single project, enabling one to reach important results, as demonstrated by the assessment of environmental achievements and the calculation of eliminated CO_2 emissions. Since a quantitative evaluation of the energy savings that can be achieved with the use of bioclimatic greenhouses is very complex due to the large number of parameters which are necessary to describe their operation, the research work focused on the thermo-fluid dynamic modelling of these systems, with the use of a specific computational fluid dynamics–finite element method software, COMSOL Multiphysics. In particular, a model was created, initially conceived in two dimensions and currently developed in three dimensions, which reproduces the thermo-fluid dynamic behaviour of an experimental greenhouse in the Solaria complex. The possibility of changing parameters characterizing materials and climatic conditions allow one to appreciate the influence on energy performance of special reinforced thermal insulation, solar control glasses and external sliding sunshades. A further added value is the possibility of simulating an organic thin-film photovoltaic device of nanometric thickness.

14/02714 TiO_2–SnO_2 nanomaterials for gas sensing and photocatalysis

Kusior, A. *et al. Journal of the European Ceramic Society*, 2013, 33, (12), 2285–2290.

Nanopowders of TiO_2–SnO_2 over a full composition range extending from 100 mol% TiO_2 to 100 mol% SnO_2 are obtained by the sol–gel method from TTIP and $SnCl_2 \cdot 5H_2O$ precursors of Ti and Sn, respectively followed by calcination at 400 °C. The samples are characterized by means of Brunauer–Emmett–Teller, X-ray diffraction and transmission electron microscopy (TEM). Optical properties of the prepared nanomaterials are studied as well. TEM images indicate that the nanoparticles are regular in shape. The specific surface area, specific surface area (SSA) of TiO_2 is 95 m^2/g while that of SnO_2 amounts to 129 m^2/g. The highest SSA of 156 m^2/g is achieved at 20 mol% of TiO_2. Occurrence of rutile, anatase and brookite polymorphic forms depends on the chemical composition of nanopowders. Formation of rutile-type solid solution of TiO_2–SnO_2 over the range of 0–80 mol% TiO_2 is confirmed by Vegard rule applied to lattice constants. Electronic band gap decreases with Ti content from 3.84 eV (100 mol% SnO_2) to 3.18 eV (100 mol% TiO_2).

14/02715 U.S. energy savings potential from dynamic daylighting control glazings

Shehabi, A. *et al. Energy and Buildings*, 2013, 66, 415–423.

Daylighting controls have the potential to reduce the substantial amount of electricity consumed for lighting in commercial buildings. Material science research is now pursuing the development of a dynamic prismatic optical element (dPOE) window coating that can continuously readjust incoming light to maximize the performance and energy savings available from daylighting controls. This study estimates the technical potential for energy savings available from vertical daylighting strategies and explores additional savings that may be available if current dPOE research culminates in a successful market-ready product. Radiance daylight simulations are conducted with a multi-shape prismatic window coating. Simulated lighting energy savings are then applied to perimeter floor space estimates generated from US commercial building stock data. Results indicate that fully functional dPOE coatings, when paired with conventional vertical daylight strategies, have the potential to reduce energy use associated with US commercial electric lighting demand by as much as 930 TBtu. This reduction in electric lighting demand represents an approximately 85% increase in the energy savings estimated from implementing conventional vertical daylight strategies alone. Results presented in this study provide insight into energy and cost performance targets for dPOE coatings, which can help accelerate the development process and establish a successful new daylighting technology.

14/02716 Visual comfort assessment of smart photovoltachromic windows

Cannavale, A. *et al. Energy and Buildings*, 2013, 65, 137–145.

An experimental study of photovoltachromic (PVCC) devices for dynamic solar control in buildings is presented. The fabricated devices underwent a complete opto-electrical characterization and the results obtained were employed as an input for the simulation of building integrated multifunctional windows. This multidisciplinary activity aims at achieving relevant feedbacks from the simulation of real large area devices in order to adjust and even direct further experimental efforts, before reaching the production phase. Devices having different electrochromic capacitances were used and the optical measurements became useful inputs for the simulation task. Simulation's results turned into feedbacks concerning the modulation of the transmittance spectra, the colour of bleached devices, the scale-up of PVCCs. Devices used in the current work showed a power peak of 4.22 mW/cm^2 at the maximum power point and a smart modulation of optical transmittance of 50.16% (at 700 nm). Simulations of natural light penetration in office buildings showed that the integration of PVCCs in traditional windows could dramatically increase indoor visual comfort. An increase of the average useful daylight illuminance for a typical room up to 71.8% and a decrease of intolerable glare levels (daylight glare probability > 0.45) down to 12% were the major benefits of the substitution of traditional clear glasses with integrated PVCCs.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

14/02717 A top-down approach to assess physical and ecological limits of biofuels

de Castro, C. *et al. Energy*, 2014, 64, 506–512.

The aim of this article is to analyse the physical and ecological limits of biofuels (in particular, ethanol). To this end, three aspects are discussed. First of all, the territorial element, i.e. the real productivity of energy crops (in particular, ethanol), to show that, in general, the productivity is much lower than most of the literature on the subject suggests. Similarly, the authors then stress the high total territorial impact (the ecological footprint) associated with this kind of energy production. Thirdly, the authors offer data concerning the very modest nature of the energy balance of biofuels and their real power density, considering the productivity of the crops grown for biofuel. As a comparison, these three aspects are estimated for other forms of energy, in particular, photovoltaic energy. It was concluded after the set of estimated parameters had been analysed, that there exists reasonable doubts concerning the use of biofuels on a regional and global scale, so they should not, in principle, be promoted as a renewable energy source, nor is it desirable on such a scale.

14/02718 Automatic fault diagnosis in PV systems with distributed MPPT

Solórzano, J. and Egido, M. A. *Energy Conversion and Management*, 2013, 76, 925–934.

This work presents a novel procedure for fault diagnosis in PV systems with distributed maximum power point tracking (MPPT) at module level. Apart from the power benefits obtained when an irregular irradiance distribution is present, this type of system permits the monitoring of the photovoltaic (PV) plant parameters at the module level: voltage and current at the working power point. With these parameters, a prototype diagnosis tool has been developed in Matlab and it has been experimentally verified in a real rooftop PV generator by applying different failures. The tool can diagnose the following failures: fixed object shading (with distance estimation), localized dirt, generalized dirt, possible hot-spots, module degradation and excessive losses in DC cables. In addition, it alerts the user of the power losses produced by each failure and classifies the failures by their severity. This system does not require the use of irradiance or temperature sensors, except for the generalized dirt failure, reducing the cost of installation, especially important in small PV systems.

14/02719 Biochar production by sewage sludge pyrolysis

Agrafioti, E. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 101, 72–78.

Sewage sludge was pyrolysed in order to assess the effect of pyrolysis temperature, residence time and biomass chemical impregnation on the yield of biochar production. The pyrolysis temperature was a key factor affecting biochar yield, while the highest yield was obtained at a temperature of 300 °C. Biochar surface area increased with increasing pyrolysis temperature and was maximized (90 m^2/g) by impregnating biochar with K_2CO_3. Raw sewage sludge, as well as biochar samples, were subjected to leaching tests in order to investigate the potential release of heavy metals. Pyrolysis suppressed heavy metal release for the non-impregnated biochars, indicating that there is no environmental risk using sludge-derived biochars as soil amendments. Although K_2CO_3 and H_3PO_4 impregnation enhanced the solubility of specific heavy metals, the concentrations in the leachates were low. Biochar impregnated with K_2CO_3 released 85.7% of its potassium content, whereas orthophosphates were bound strongly in the biochar matrix impregnated with H_3PO_4. The non-impregnated biochar was subjected to batch kinetic experiments in order to examine its ability to adsorb As(V) and Cr(III). Biochar removed approximately 70% of Cr(III) at equilibrium time, whereas only 30% of As(V) was adsorbed onto biochar surface, implying that biochar is more efficient in removing cations than anions from aqueous solutions.

14/02720 Codigestion of Taihu blue algae with swine manure for biogas production

Miao, H. *et al. Energy Conversion and Management*, 2014, 77, 643–649.

Anaerobic digestion (AD) of Taihu blue algae and its codigestion with swine manure was evaluated at different inoculum substrate ratios (ISRs) from 0.5 to 3.0. Results showed that codigestion of blue algae with swine manure led to the highest methane (CH_4) production of 212.7 $mL\,g^{-1}$ volatile solids (VS) at ISR 2.0, while digestion of blue algae inoculated with granular sludge brought out the optimized CH_4 production of 73.5 $mL\,g^{-1}$ VS at an ISR of 3.0. The values of pH, total ammonia nitrogen, free ammonia nitrogen (N-NH_3) and volatile fatty acids (VFAs) showed no significant difference between the digestion and codigestion, confirming the appropriate stability of the two batch anaerobic processes. Closer examination of VS removal rates and key enzymes variation proved codigestion had higher efficiencies in biodegradation and methanation, which demonstrated that AD of blue algae with swine manure was a promising technology for both solid waste treatment and renewable-energy production.

14/02721 Ethyl acetoacetate: a potential bio-based diluent for improving the cold flow properties of biodiesel from waste cooking oil

Cao, L. *et al. Applied Energy*, 2014, 114, 18–21.

Ethyl acetoacetate was investigated as a potential bio-based diluent for improving the cold flow properties of biodiesel from waste cooking oil. Waste cooking oil generally has relatively high saturated fatty acid content, meaning that the cold flow properties of the converted biodiesel are more challenging than the properties of biodiesel from conventional vegetable oils. The cold filter plugging point (CFPP) and pour point (PP) of biodiesel decreased after adding ethyl acetoacetate at 0%, 2.5%, 5%, 10% and 20% (vol). Both PP and CFPP decreased by 4 °C at 20 vol% ethyl acetoacetate. The effect of ethyl acetoacetate on kinematic viscosity, acid value and flash point was determined. Every sample satisfied ASTM D6751 except for the flash point ($\geq$10 vol% ethyl acetoacetate), but the 5 vol% blends were all acceptable. Oxidative stability was improved with the addition of ethyl acetoacetate. Overall, ethyl acetoacetate appears acceptable as a bio-based diluent for improving the cold flow properties of biodiesel.

14/02722 Fractionation of olive mill wastewaters by membrane separation techniques

Cassano, A. *et al. Journal of Hazardous Materials*, 2013, 248–249, 185–193.

This study aims to evaluate the potential of an integrated membrane system in the treatment of olive mill wastewaters (OMWs) to produce a purified fraction enriched in low molecular weight polyphenols, a concentrated fraction of organic substances and a water stream which can be reused in the extractive process of olive oil. In particular, a sequence of two ultrafiltration processes followed by a final nanofiltration step was investigated on laboratory scale operating in selected process parameters. The produced fractions were analysed for their total content of polyphenols, total antioxidant activity, free low molecular weight polyphenols and total organic carbon. The performance of selected membranes in terms of productivity, fouling index and selectivity toward compounds of interest was also evaluated and discussed. An integrated membrane process was proposed to achieve high levels of purification of OMWs and a water fraction which can be discharged in aquatic systems or to be reused in the olive oil extraction process.

14/02723 Greenhouse gas emissions and energy balances of jatropha biodiesel as an alternative fuel in Tanzania

Eshton, B. *et al. Biomass and Bioenergy*, 2013, 58, 95–103.

This paper evaluates greenhouse gas (GHG) emissions and energy balances [i.e. net energy value (NEV), net renewable energy value (NREV) and net energy ratio (NER)] of jatropha biodiesel as an alternative fuel in Tanzania by using life cycle assessment approach. The functional unit (FU) was defined as 1 tonne (t) of combusted jatropha biodiesel. The findings of the study prove wrong the notion that biofuels are carbon neutral, thus can mitigate climate change. A net GHG equivalent emission of about 848 $kg\,t^{-1}$ was observed. The processes which account significantly to GHG emissions are the end use of biodiesel (about 82%) followed by farming of jatropha for about 13%. Sensitivity analysis indicates that replacing diesel with biodiesel in irrigation of jatropha farms decreases the net GHG emissions by 7.7% while avoiding irrigation may reduce net GHG emissions by 12%. About 22.0 GJ of energy is consumed to produce 1 t of biodiesel. Biodiesel conversion found to be a major energy consuming process (about 64.7%) followed by jatropha farming for about 30.4% of total energy. The NEV is 19.2 $GJ\,t^{-1}$, indicating significant energy gain of jatropha biodiesel. The NREV is 23.1 $GJ\,t^{-1}$ while NER is 2.3; the two values indicate that large amount of fossil energy is used to produce biodiesel. The results of the study are meant to inform stakeholders and policy makers in the bioenergy sector.

14/02724 'Methano-compost', a booster and restoring agent for thermophilic anaerobic digestion of energy crops

Scherer, P. and Neumann, L. *Biomass and Bioenergy*, 2013, 56, 471–478.

The influence of plant litter-compost of the hot rotten-phase as additional inoculum for anaerobic batch digestion of sugar beet silage was studied. Four simultaneously driven batch-fermenters were inoculated with sewage sludge. Two of the fermenters were inoculated additionally with the same amount of organics by compost of the hot rotten-phase. Two of the fermenters were mesophilic (40 °C) and the other two were thermophilic (60 °C). The impact on the gas production rate and gas yield was observed to be boosted for thermophilic (60 °C) and only a minor effect of 6–13% for mesophilic (40 °C) digestion. The gas yield increased considerably up to 26.5% at 60 °C (batch). Also the methane content increased from 57.4% to 62.3% by adding compost (continuously run mesophilic digestion). Fluorescence *in situ* hybridization (FISH) indicated that a microbial effect was responsible for the observed stimulation of gas production rates, but not simply by increasing the bacterial counts. By analysing each fermenter for its mineral and trace element content a mineralic effect could be excluded. However, the bacterial counts by FISH of 10 different groups were somewhat ambiguous. But an effect on the presence of Chloroflexi could be demonstrated. They nearly doubled to 15–16% by supplementation with compost. Furthermore, under thermophilic conditions, the added compost induced a significant shift in the microbial composition towards hydrogenotrophic Methanobacteriales. The suggestive conclusion drawn is that this explicitly increase in hydrogenotrophic activity could alone or in combination with accompanying fermentative bacteria forces the microbial food chain towards stimulation of methane generation.

14/02725 Modeling price-driven interactions between wood bioenergy and global wood product markets

Zhang, S. *et al. Biomass and Bioenergy*, 2014, 60, 68–78.

Higher and more volatile liquid fossil fuel prices have had profound effects on international energy and wood product markets. Understanding this evolving economic and technological landscape requires economic models that capture the interconnections between energy markets and wood product markets, and can be used to forecast the impact of alternative policy and market incentives. The need for such an analytic framework is underscored by the consensus that efficiently produced wood bioenergy could provide many climate benefits compared to fossil-fuel intensive substitutes. A model is presented for analysis of how increased use of wood bioenergy, in the forms of fuel wood, cellulosic ethanol from woody biomass, and electricity produced from wood, might interact with global markets for wood products; liquid, solid, and gaseous fuels; and electricity produced from other sources. It links US energy markets with wood product markets and endogenizes the demand for wood bioenergy with price-driven market clearing mechanisms. Projections made with the model point to a substantial increase in demand for woody cellulosic ethanol in the USA for the next 30 years if oil prices remain high.

14/02726 Multi-actor governance of sustainable biofuels in developing countries: the case of Mozambique

Schut, M. *et al. Energy Policy*, 2014, 65, 631–643.

This paper describes and analyses the multi-actor governance process that made Mozambique the first African nation-state to develop a national policy framework for sustainable biofuels. The paper draws on findings from action research conducted in Mozambique between December 2008 and July 2012. The authors analyse interactions between the changing governance context, the course of the multi-actor governance process, and the choices in relation to governance framework characteristics and content for four successive stages of governance framework development. This provides the basis for reflection on the competences required for effective multi-actor sustainability governance, and a discussion about the role of the nation-state in sustainability governance of global economies such as biofuels. The governance framework for sustainable biofuels has contributed to a more transparent and secure investment climate for biofuels in Mozambique. Key factors for success were: (1) the presence of different types of competences during the various stages of the governance framework development, (2) closing the gap between 'licences to sell' and 'licences to produce' across different governance levels and (3) balancing between the short- and long-term objectives for biofuel production in Mozambique and requirements of global biofuel markets. Developing-country nation-states can provide an essential contribution to these success-factors for global governance of sustainable biofuels.

14/02727 Optimizing biofuels production in an uncertain decision environment: conventional vs. advanced technologies

Ziolkowska, J. R. *Applied Energy*, 2014, 114, 366–376.

The question of increasing biofuel production and the development of different biofuel production technologies has become controversial. On the one hand, production of corn-based biofuels creates a 'food/feed vs fuel' trade-off condition, along with subsequent uncertainties for both consumers and producers (farmers). On the other, advanced biofuels (from switchgrass, Miscanthus and algae, for example), although acknowledged as environmentally friendly, are not available on a large commercial scale yet. In addition, the limited resource availability for the production of biofuels feedstocks and the question of a sustainable biofuels production are major issues impacting decision making. Most recently, climatic conditions and the 2011–2012 drought in the USA have imposed new uncertainties that need to be considered in the policy-making processes. By using a multi-objective optimization model, this paper presents an approach of modelling sustainable biofuels production from conventional and advanced biofuels feedstocks, under the condition of limited resources and uncertainty resulting from incomplete information or missing knowledge about the consequences of possible policy actions.

14/02728 Production and characterization of biodiesel obtained from *Sapindus mukorossi* kernel oil

Chakraborty, M. and Baruah, D. C. *Energy*, 2013, 60, 159–167.

Sapindus mukorossi is a tree that grows in the north-eastern region of India. The fruit of *S. mukorossi* has some traditional uses and its kernel contains 39% (w/w) oil. The prospect of *S. mukorossi* oil for biodiesel production is investigated with reference to some relevant properties. The fatty acid profile of oil extracted from *S. mukorossi* is found comparable with similar seed oils attempted for biodiesel production in this region. Since the acid value of *S. mukorossi* is found to be 15.6 mgKOH/g, so biodiesel is prepared using two-stage transesterification. In the first step, alcohol-to-oil molar ratio of 6 : 1 with 1 wt% of H_2SO_4, results the maximum reduction in acid value (acid value 1.89 mgKOH/g) within 60 min. In the second step, 10 : 1 alcohol-to-oil molar ratio and 1 wt% $NaOCH_3$ gives the optimum yield of biodiesel. Finally, the biodiesel is confirmed by the peaks appeared in ^1H nuclear magnetic resonance (NMR) and ^{13}C NMR. The properties of the biodiesel are obtained using standard ASTM techniques and found to conform to the existing norms.

14/02729 Production of biodiesel from palm oil using modified Malaysian natural dolomites

Shajaratun Nur, Z. A. *et al. Energy Conversion and Management*, 2014, 78, 738–744.

Calcined dolomite (AD), produced by calcination of Malaysian dolomite promotes a potential natural catalyst for biodiesel production from palm oil with the conversion of 99.98%. The catalysts were characterized by using X-ray diffractometer, Brunauer–Emmet–Teller surface area, scanning electron microscopy and temperature programmed desorption of CO_2. All catalysts were then employed for transesterification reaction under different conditions (time, methanol-to-oil molar ratio and amount of catalyst). SnO_2 doped on activated dolomite shows an optimum conversion (99.98%) at 15 : 1 methanol-to-oil molar ratio in 4 h compared to ZnO doped on activated dolomite and AD. The catalytic activities of these catalysts were found to depend on the basicity as well as the surface area of the catalyst used.

14/02730 Remote monitoring system for stand-alone photovoltaic power plants: the case study of a PV-powered outdoor refrigerator

Tina, G. M. and Grasso, A. D. *Energy Conversion and Management*, 2014, 78, 862–871.

This paper describes a monitoring architecture for stand-alone photovoltaic (SAPV) systems. For the proposed system, a web application has been adopted, thus allowing an on-line monitoring and control of remote installations. Moreover, daily reports are elaborated and sent to the system operator. These data can be analysed off-line to calculate both energy performances indices and statistical values. Historical data analysis is useful not only to optimize the operation of the system but also to design a retrofit of the SAPV system. To check the effectiveness of the proposed remote monitoring system, the performance of a PV-powered outdoor refrigerator has been evaluated. In cases of temperature-sensitive applications, such as storage of vaccines or perishable goods, critical operating conditions have been detected. Experimental measurements executed on a prototype, adapted for outdoor operation with a horizontal PV module, show that the refrigerator works adequately in the given place (Catania, Italy), where a typical Mediterranean climate is present, if an additional vertical PV module is adopted.

14/02731 Scenario-based strategic supply chain design and analysis for the forest biorefinery using an operational supply chain model

Mansoornejad, B. *et al. International Journal of Production Economics*, 2013, 144, (2), 618–634.

Supply chain (SC) design involves decisions for the long term, e.g. determining products, process technologies, number, location and capacity of different SC nodes, production rates, as well as suppliers, markets and partners. The forest biorefinery (FBR) is emerging as a new possibility for improving forestry companies' business models, however introduces significant technological, economic and financial challenges, which can be systematically addressed in strategic SC design. In order to reduce the burden of such challenges, partnership with companies whose expertise brings value and experience to the forestry companies' new business model is essential for FBR implementation. In this regard, redesigning the forestry SC in order for it to be aligned and consistent with the partner's SC, and in other words, designing a new integrated SC is of crucial importance. This paper presents a scenario-based approach to strategic SC design for the FBR, designing the SC based on the impacts of the design on operational SC activities. Two kinds of scenarios are used; market scenarios representing market volatility and SC network scenarios (referred to as alternatives) representing different biorefinery options/strategies. In order to analyse the impacts of SC alternatives on operational activities, a tactical/operational SC model examines the advantages and disadvantages of each alternative by exploiting the capability of the SC for flexibility in the case of the market scenario realization. This demonstrates the impact of each scenario on SC profitability. It will also show how integration scenarios may result in better economic performances compared to the case when the forestry company implements the biorefinery on its own and hence, it reveals how forestry companies can benefit from the created synergies.

14/02732 Straw potential for energy purposes in Poland and optimal allocation to major co-firing power plants

Rozakis, S. *et al. Biomass and Bioenergy*, 2013, 58, 275–285.

Agricultural waste and especially straw can provide a significant share of biomass energy. However, due to the very nature of agricultural production, as well as a need for carbon sequestration in soils and other aspects of food production, only part of the straw potential may be treated as waste and spent on energy production. Based on statistical data from the Polish Central Statistical Office the actual production of straw was modelled on a scale of local districts as well as the needs of its local use and the possibility of redistribution of excessive quantities to regions with a deficit of straw. As a result, the straw surplus that could be used in the energy sector was obtained along with its geographical distribution. Next, a cost-minimizing transport model is used to optimize the straw's allocation among main power plants all over the country, taking into account capacities and technical constraints of co-firing biomass with coal. The results are detailed at the municipal level indicating excess capacity for biomass co-firing by plant and regions to be satisfied by additional biomass sources such as biomass from forest or energy plantations.

14/02733 Study of bio-oil and bio-char production from algae by slow pyrolysis

Chaiwong, K. *et al. Biomass and Bioenergy*, 2013, 56, 600–606.

This study examined bio-oil and bio-char fuel produced from *Spirulina* Sp. by slow pyrolysis. A thermogravimetric analyser was used to investigate the pyrolytic characteristics and essential components of algae. It was found that the temperature for the maximum degradation, 322 °C, is lower than that of other biomass. With the fixed-bed reactor, 125 g of dried *Spirulina* Sp. algae was fed under a nitrogen atmosphere until the temperature reached a set temperature between 450 and 600 °C. It was found that the suitable temperature to obtain bio-char and bio-oil were at approximately 500 and 550 °C, respectively. The bio-oil components were identified by a gas chromatography/mass spectrometry. The saturated functional carbon of the bio-oil was in a range of heavy naphtha, kerosene and diesel oil. The energy consumption ratio (ECR) of bio-oil and bio-char was calculated, and the net energy output was positive. The ECR had an average value of 0.49.

14/02734 Study of fuel properties of rubber seed oil based biodiesel

Ahmad, J. *et al. Energy Conversion and Management*, 2014, 78, 266–275.

The scarcity of the fossil fuel, environmental pollution and food crisis are the world's major issues in current era. Biodiesel is an alternative to diesel fuel, environment friendly and biodegradable and is produced from either edible or non-edible oils. In this study, a non-edible rubber seed oil (RSO) with high free fatty acid (FFA) content of 45% were used for the production of biodiesel. The process comprises of two steps. The first step is the acid esterification to reduce the FFA value and the second step is the base transesterification. The response surface methodology (RSM) was used for parametric optimization of the two-stage processes, i.e. acid esterification and base transesterification. The yield of biodiesel was analysed using gas chromatography. The Fourier transform infrared spectrum was also determined to confirm the conversion of fatty acid to methyl esters. The fuel properties were analysed according to ASTM D6751 and EN14214 and were compared with the previous findings of researchers. All analysed properties fulfilled the biodiesel standard criteria.

14/02735 TGA study examining the effect of pressure and peak temperature on biochar yield during pyrolysis of two-phase olive mill waste

Manyà, J. J. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 86–95.

In this paper, a factorial design of experiments was proposed to investigate the effect of the absolute pressure (in the range 0.1–1.5 MPa) and the peak temperature (in the range 400–550 °C) on the pyrolysis behaviour of two-phase olive mill wastes (TPOMW). Pyrolysis experiments were conducted in a thermogravimetric analyser (TGA) under nitrogen atmosphere and at a linear heating rate of $5\,\mathrm{K\,min^{-1}}$. The response variables (biochar yield, fixed-carbon yield, and the temperature at which the maximum rate of weight loss is reached) were analysed using regression models. From results of regression analyses, the following main conclusions can be drawn: (a) biochar yield from pyrolysis of TPOMW decreases when both peak temperature and pressure increases; (b) an increase of both peak temperature and pressure results in a higher fixed-carbon yield; and (c) a significant increase of the overall devolatilization rate was observed for experiments conducted at intermediate pressure values (0.8 MPa). In addition to this, kinetic parameters describing TPOMW pyrolysis were estimated adopting a devolatilization scheme based on separate volatilized fractions generated from three pseudo-components. The quality of the fit between experimental weight-loss data and computed values (using an independent parallel reaction kinetic model) was found to be remarkably good.

14/02736 The effect of native and introduced biofuel crops on the composition of soil biota communities

Hedĕnec, P. *et al. Biomass and Bioenergy*, 2014, 60, 137–146.

Biofuel crops are an accepted alternative to fossil fuels, but little is known about the ecological impact of their production. The aim of this contribution is to study the effect of native (*Salix viminalis* and *Phalaris arundinacea*) and introduced (*Helianthus tuberosus*, *Reynoutria sachalinensis* and *Silphium perfoliatum*) biofuel crop plantations on the soil biota in comparison with cultural meadow vegetation used as control. The study was performed as part of a split plot field experiment of the Crop Research Institute in the city of Chomutov in the Czech Republic. The composition of the soil meso- and macrofauna community, composition of the cultivable fraction of the soil fungal community, cellulose decomposition (using litter bags), microbial biomass, basal soil respiration and phospholipid fatty acid composition (incl. F/B ratio) were studied in each site. The C : N ratio and content of polyphenols differed among plant species, but these results could not be considered significant between introduced and native plant species. Abundance of the soil meso- and macrofauna was higher in field sites planted with *S. viminalis* and *P. arundinacea* than those planted with *S. perfoliatum*, *H. tuberosus* and *R. sachalinensis*. Redundancy analysis and a Monte Carlo permutation test showed that the composition of the faunal community differed significantly between various native and introduced plants. Significantly different basal soil respiration was found in sites planted with various energy crops; however, this difference was not significant between native and introduced species. Microbial biomass carbon and cellulose decomposition did not exhibit any statistical differences among the biofuel crops. The largest statistically significant difference found was in the content of actinobacterial and bacterial (bacteria, G+ bacteria and G− bacteria) PLFA in sites overgrown by *P. arundinacea* compared to introduced as well as native biofuel crops. In conclusion, certain parameters significantly differ between various native and introduced species of biofuel crops; however, the functional importance of these differences requires further research.

14/02737 The electric energy potential of landfill biogas in Brazil

Barros, R. M. *et al. Energy Policy*, 2014, 65, 150–164.

The increases in a country's energy capacity are related to its gross domestic product (GDP). In Brazil, increases in income and the consumption of goods and services have led to an increase in the generation of solid waste (SW), which is sent to landfills as a method of treatment and final disposal. The purpose of this study was to facilitate an increase in energy generation from renewable resources, specifically from landfills via thermal biogas plants, and the research was divided into two phases. The first phase involved the assessment of the potential population size contributing to the landfill, which could result in the installation of a financially viable enterprise to generate electricity in Brazil. Next, an estimate of the costs associated with the generation and collection of solid waste in Brazil was predicted by GDP prognoses, the latter being in accordance with the National Energy Balance (Balanço Energético Nacional – BEN) plan created by the Mines and Energy Ministry of Brazil (Ministério de Minas e Energia do Brasil – MME). The net present value and internal rate of return of each enterprise scenario was used in the first stage to assess the plan's financial viability. In the second stage, estimation curves such as logistics, decreasing rate of growth, and logarithmic curves were used to establish relationships between the generation scenarios and the projected collection of SW and projected GDP. Thus, a range of possible landfill biogas/methane generation values and installed energy capacities were created, considering the extreme maximum and minimum values. These values were related to the energy sources from residual fuels reported by BEN. The results demonstrated that such values still represented a small percentage (0.00020% in 2010 and 0.44496–0.81042% in 2030) of the projected energy generation from residual fuels. Thus, an urgent need was identified to formulate policies that would encourage landfills as a source of renewable energy, broadening the number of financially viable initiatives for energy generation from landfill biogas for populations of fewer than 200,000 inhabitants.

14/02738 Thermal cracking of *Enteromorpha prolifera* with solvents to bio-oil

Song, L. *et al. Energy Conversion and Management*, 2014, 77, 7–12.

Enteromorpha prolifera is a renewable energy source that was evaluated as a feedstock to produce bio-oil by thermal cracking. Harvesting *E. prolifera* for bio-oil production will also reduce the damage of green tides on the ocean ecology. Effects of reaction temperature between 220 and 380 °C and reaction time between 20 and 80 min on the bio-oil yield and gas and solid thermal cracking products were investigated. Effects of solvents (i.e. ethanol and vacuum gas oil, VGO) on the yields of bio-oil, gas and solid were also studied. *E. prolifera*, VGO and products from thermal cracking were analysed by elemental analysis, gas chromatography–mass spectra and gas chromatography. Results indicate that thermal cracking of *E. prolifera* with VGO gave rise to the maximum bio-oil yield of 90.5% at 300 °C with a reaction time of 30 min. Higher heating values and elemental analysis demonstrate that this process has the potential for industrial production of bio-oil from *E. prolifera*.

14/02739 Ultrasound-enhanced conversion of biomass to biofuels

Luo, J. *et al. Progress in Energy and Combustion Science*, 2014, 41, 56–93.

Two important challenges need to be addressed to realize a practical biorefinery for the conversion of biomass to fuels and chemicals: (i) effective methods for the degradation and fractionation of lignocelluloses and (ii) efficient and robust chemical methods for the conversion of bio-feeds to target products via highly selective catalytic reactions. Ultrasonic energy promotes the pretreatment and conversion process through its special cavitational effects. In this review, recent progress and methods for combining and integrating sonication into biomass pretreatment and conversion for fuels and chemicals are critically assessed. Ultrasonic energy combined with proper solvents allows destruction of the recalcitrant lignocellulosic structure, fractionation of biomass components, and then assists many thermochemical and biochemical reactions, with increased equilibrium yields of sugars, bio-ethanol and gas products by 10–300%. Sonication promotes hydrolysis, esterification and transesterification in biodiesel synthesis and leads to reduced reaction time by 50–80%, lower reaction temperature, less amounts of solvent and catalyst than comparable unsonicated reaction systems. For algal biomass, sonication benefits the disruption, lysis and content release of macroalgae and microalgae cells, and reduces the time required for subsequent extraction and chemical/biochemical reactions, with efficiencies typically being improved by 120–200%. High-frequency ultrasound of 1–3 MHz allows harvesting of microalgae, liquid product separation and *in situ* process monitoring of biomass reactions, while high-intensity ultrasound at 20–50 kHz activates heterogeneous and enzymatic catalysis of the biomass reactions. The use of ultrasound in conversion of biomass to biofuels provides a positive process benefit.

14/02740 Whole sample analysis of bio-oils and thermal cracking fractions by Py-GC/MS and TLC–FID

Alsbou, E. and Helleur, R. *Journal of Analytical and Applied Pyrolysis*, 2013, 101, 222–231.

A combination of pyrolysis-gas chromatography/mass spectroscopy (GC/MS) and thin-layer chromatography–flame ionization detection (TLC–FID) techniques were used for whole sample analysis of bio-oil samples obtained from different liginocellulosic biomasses, (i.e. birch wood, pine wood, barley straw and forest residue and thermal-cracking fractions). Both techniques showed the ability to analyse the whole sample without clean-up or fractionation and to distinguish among the bio-oils based on their feedstock sources. The TLC–FID is a chromatographic method whereby the oil solution is spotted on a thin-layer chromatography rod, developed by a two solvent system and the chromatographic bands measured by flame ionization detection (FID). The pyrolysis (py)-GC/MS instrument uses a sample cup and a vertical microfurnace to analysis bio-oils. The non-volatiles fraction remaining in the cup were weighed after thermal evaporation-GC/MS. The hardwood birch bio-oil was shown to have syringol and its derivatives compared to pine wood and barley straw bio-oils that were shown to have methoxyphenolic and non-methoxy-phenolic compounds, respectively. TLC–FID shows clear differences in the peak areas and shapes for the bio-oils fractions by solvent development on chromarods and are in agreement with the results obtained by Py-GC/MS. Furthermore, forest residue bio-oil and its thermal cracking fractions could be effectively characterized by TLC–FID (and Py-GC/MS) whereby the light fraction was composed of a wide range of lower polarity compounds while middle and heavy fraction had higher polarity compounds.

Geothermal energy

14/02741 A reactive thermo-poroelastic analysis of water injection into an enhanced geothermal reservoir

Rawal, C. and Ghassemi, A. *Geothermics*, 2014, 50, 10–23.

Coupled thermoporochemomechanical processes in geothermal systems impact the reservoir response during injection and production procedures by affecting fracture permeability. A three-dimensional numerical model is presented to analyse these processes during fluid injection into geothermal reservoirs. The solid mechanics aspect of the problem is computed using the displacement discontinuity boundary element method (BEM) while transport processes within the facture are modelled using the finite element method (FEM). The FEM and BEM formulations are integrated to set up a system of equations for unknown temperature, pressure, concentration, and fracture aperture. The fluid diffusion, heat conduction and solute diffusion in the reservoir are treated using BEM so that the need of infinite reservoir domain discretization is eliminated. The numerical model is used to analyse the fracture response to non-isothermal reactive flow in enhanced geothermal systems. Numerical examples of SiO_2 undersaturated-cold water injection into the geothermal reservoir show that silica dissolves from the rock matrix, increasing the fracture aperture. The zone of silica dissolution spreads into the fracture with continuous fluid injection. At large injection times, thermoelastic stress has a greater impact on fracture aperture compared to poroelastic stress. Simulations that consider natural fracture stiffness heterogeneity show the development of a non-uniform flow path within the crack, with lower rock matrix cooling and thus enhanced silica reactivity in the high stiffness regions. As a result, areas of higher joint normal stiffness show lower aperture increases in response to the thermoporoelastic processes, but a higher aperture expansion due to silica dissolution. Depending on the injectate saturation state with respect to quartz, silica is added or removed from the rock matrix. This process is likely to impact the rock matrix properties and its mechanical response to stress perturbations associated with fluid circulation.

14/02742 A simple 3-D thermoelastic model for assessment of the long-term performance of the Hijiori deep geothermal reservoir

Jing, Y. *et al. Journal of Volcanology and Geothermal Research*, 2014, 269, 14–22.

In order to assess the thermoelastic influence on the long-term performance of hot dry rock (HDR) reservoirs, a simple three-dimensional (3-D) thermoelastic model has been developed based on an assumption of a spherically symmetric volume of cooled rock within reservoir. This model has been incorporated into a 3-D stochastic network model, FRACSIM-3D, which incorporates a fracture network designed to mimic natural fracture distributions as well as stimulation and circulation. The model has been used to evaluate the possible long-term performance of the deep HDR reservoir at Hijiori, Japan. Simulation results showed that thermoelasticity could exert a significant influence on production temperature, injection pressure and water loss. For a multi-well geothermal system, thermoelasticity seemed to have a potential to cause the development of high flow rate/rapidly cooling flow paths (thermal short circuits).

14/02743 An analytical approach to evaluating the effect of thermal interaction of geothermal heat exchangers on ground heat pump efficiency

Koohi-Fayegh, S. and Rosen, M. A. *Energy Conversion and Management*, 2014, 78, 184–192.

A semi-analytical model that couples a model outside the borehole with one inside the borehole is proposed. To examine the effect of temperature rise in the soil surrounding a vertical ground heat exchanger on the performance of an associated ground heat pump, the heat pump model should be coupled to the model inside the borehole and the conduction heat transfer model outside the borehole. The running fluid temperature, the borehole wall temperature and the heat load profile are the main coupling parameters between the three models. The results of the analytical model are compared with ones of a finite volume numerical model.

14/02744 Analysis of short helical and double U-tube borehole heat exchangers: a simulation-based comparison

Zarrella, A. *et al. Applied Energy*, 2013, 112, 358–370.

This paper makes a comparative analysis between a helical-shaped pipe and a double U-tube ground heat exchanger. The two configurations were installed at a shallow depth and studied, since a depth limit is mandatory in some areas. When installed this way, the interaction between the ground surface and the ambient environment needs to be taken into account when the thermal behaviour of the ground heat exchangers is investigated. A detailed numerical simulation tool was used to carry out this research. The problem of heat transfer was solved with an equivalent electrical circuit of thermal resistances and capacitances. This simulation tool was also used on a double U-tube heat exchanger in order to include axial heat conduction in the ground and the borehole. The two borehole heat exchangers were analysed over both long- and short-term periods; the thermal properties of the ground, energy loads and the axial effects of weather conditions were also taken into account. Finally, a reduction in the borehole length for the helical-shaped pipe was also assessed and compared with the performance of the double U-tube.

14/02745 Application of conventional and advanced exergy analyses to evaluate the performance of a ground-source heat pump (GSHP) dryer used in food drying

Erbay, Z. and Hepbasli, A. *Energy Conversion and Management*, 2014, 78, 499–507.

Inefficiencies in an energy system can be quantitatively determined through conventional exergy analysis while sources of the irreversibilities and real improvement potential can be deducted using advanced exergy analysis, a relatively new method. An advanced exergy analysis is applied to a ground-source heat pump drying system used in food drying for evaluating its performance along with each component in this study. The results indicate that the most important system component is the condenser, due to the design standpoint. The inefficiencies within the compressor could particularly be improved by structural improvements of the whole system and the remaining system components. Furthermore, the inefficiencies of other system components except for the condenser and the evaporator are mainly affected by the internal operating condition. Both the equipment design and system components' interactions of the condenser and the evaporator have a significant effect on their inefficiencies. The conventional and modified (advanced) exergy efficiency values are calculated to be 77.05% and 93.5%, respectively.

14/02746 Energy performance and thermal impact of a borehole heat exchanger in a sandy aquifer: influence of the groundwater velocity

Angelotti, A. *et al. Energy Conversion and Management*, 2014, 77, 700–708.

In a saturated soil, groundwater flow affects both the energy performance and the thermal impact on the surrounding soil of borehole heat exchangers linked to ground-source heat pumps. In this paper, a numerical model in MODFLOW/MT3DMS of a single U-pipe in a sandy aquifer is proposed in order to investigate the two issues in a coupled approach. After validating the model, the typical yearly operation of a borehole heat exchanger extracting and injecting heat into the ground is simulated. For $0.1 \leq Pe \leq 1$ cold and warm plumes develop and the heat rate increases non-linearly from 11% to 105%.

14/02747 Energy performance strategies for the large scale introduction of geothermal energy in residential and industrial buildings: the GEO.POWER project

Giambastiani, B. M. S. *et al. Energy Policy*, 2014, 65, 315–322.

Use of shallow geothermal energy, in terms of ground-coupled heat pumps (GCHP) for heating and cooling purposes, is an environmentally friendly and cost-effective alternative with potential to replace fossil fuels and help mitigate climate change. Focusing on the recent results of the GEO.POWER project, this paper aims at examining the energy performance strategies and the future regional and national financial instruments for the large-scale introduction of geothermal energy and GCHP systems in both residential and industrial buildings. After a transferability assessment to evaluate the reproducibility of some outstanding examples of systems currently existing in Europe for the utilization of shallow geothermal energy, a set of regulatory, economic and technical actions is proposed to encourage the GCHP market development and support geothermal energy investments in the frame of the existing European normative platforms. This analysis shows that many European markets are changing from a new GCHP market to growth market. However some interventions are still required, such as incentives, regulatory framework, certification schemes and training activities in order to accelerate the market uptake and achieve the main European energy and climate targets.

14/02748 Evaluation of geothermal energy in desalination by vacuum membrane distillation

Sarbatly, R. and Chiam, C.-K. *Applied Energy*, 2013, 112, 737–746.

This paper presents the energy evaluation of the cross-flow vacuum membrane distillation (VMD) for three types of lab-fabricated polyvinylidene fluoride (PVDF) membranes and the commercial Westran S PVDF membrane. Membranes with the effective area 23.5 cm^2 are tested with distilled water and geothermal water as the feed solutions. Results show that the membrane porosity controlled the flux through the fabricated membranes and the commercial membrane. The commercial membrane with porosity of approximately 76.5%, which was the most porous among the tested membranes, gave the highest flux at 9.28 kg/m^2 h under the optimum conditions of 33.2 L/h feed flow rate and 30 kPa downstream pressure. The corresponding specific energy consumption was 66.03 kW/kg h^{-1} when distilled water was examined. Heating energy of 87–89 kW/kg h^{-1}, which is approximately 95% of the total energy consumption, could be saved when the warm geothermal water is fed directly into the VMD system. The water produced meets the drinking water quality with the TDS varying between 102 and 119 ppm, thus the geothermal water desalination using the VMD system to produce the drinking water is satisfactory. An economic analysis for a 20,000 m^3/d VMD desalination plant finds that the water production costs are \$0.50/m^3 and \$1.22/m^3 respectively for the plant operated with and without geothermal energy (GE). Compare to the plant without GE utilization, the water production costs of the plant operated with GE are less than \$0.50/m^3 that is at least \$0.72/m^3 or approximately 59% in cost saving when the water fluxes are larger than 6.6 kg/m^2 h. The specific membrane cost reduced from \$0.058/m^3 to \$0.035/m^3 when the membrane life extended from 3 to 5 years.

14/02749 Exergoeconomic analysis of a district heating system for geothermal energy using specific exergy cost method

Alkan, M. A. *et al. Energy*, 2013, 60, 426–434.

This study presents the exergoeconomic analysis and evaluation in order to provide cost based information and suggests possible locations/components in a geothermal district heating system (GDHS) for improving the cost effectiveness. The analysis is based on the specific exergy costing (SPECO) method, and used to calculate exergy-related parameters and display cost flows for all streams and components. As a real case study, the Afyon GDHS in Turkey is considered based on actual operational data. The obtained results show that the unit exergy cost of heat produced by the Afyon GDHS is calculated as average 5624 \$/h. The heat exchanger (HEX)-III among all components should be improved quickly due to the high total operating cost rate and relative cost difference. The HEX-I and pump-V have the highest exergoeconomic factors among all other system components due to the high owning and operating costs of these components. The heat production costs per exergy unit for all the HEXs decrease due to the high exergy destruction cost rate of the system, while the well-head temperature and ambient temperature increase. The SPECO method may be used to improve the cost effectiveness according to exergy rates in GDHSs as a thermal system.

14/02750 Exergy analysis and optimization of Dieng single-flash geothermal power plant

Pambudi, N. A. *et al. Energy Conversion and Management*, 2014, 78, 405–411.

Exergy analysis and optimization of a single-flash geothermal power plant are conducted by developing a mathematical model that is applied to the Dieng geothermal power plant in Indonesia. Calculations are conducted by using the Engineering Equation Solver code with methods based on the laws of thermodynamics. The exergy flow and efficiency are computed at several plant components, including the separator, turbine, condenser, and for the whole power plant. The exergy of the geothermal fluid that is discharged from the production wells is estimated to be 59.52 MW. This amount of fluid produces 21.71 MW of electricity from the power plant overall, with second law efficiency to be 36.48%. There is a considerable amount of waste brine, amounting to 17.98% (10.70 MW) of the total available exergy, which is disposed of in the plant's reservoir. The optimization of the plant is carried out by adjusting the separator pressure. The results show that a slight increase of 20 kW in the output power can be attained by lowering the separator pressure to 9 from 10 bar. A Grassmann diagram shows the exergy losses at each component in the power plant. The turbine and separator losses are 7.51 MW (12.62%) and 8.04 MW (13.5%), respectively, while the cooling tower has an exergy loss of 2.62 MW (4.40%). The total condenser loss is 5.8 MW (9.75%).

14/02751 Experimental measurements and CFD simulation of a ground source heat exchanger operating at a cold climate for a passive house ventilation system

Flaga-Maryanczyk, A. *et al. Energy and Buildings*, 2014, 68, 562–570.

This paper presents the experimental measurements and numerical simulation of a ground source heat exchanger operating at a cold climate for a passive house ventilation system. The investigated passive house is a detached, single-family house without a basement, occupied by a four-person family, located in the south of Poland. The measurements cover over a year's period and computational fluid dynamics (CFD) simulations are reported for February when system operates at typical for this period and location cold climate conditions. The calculations were made with the CFD ANSYS FLUENT software package. The house and its components are fitted with a data acquisition system that is operational from 2011 and records 139 points at an interval of 1 min. The data reported in the paper were recorded during winter in the year 2011/2012 by an onside located meteorological station and temperature sensors placed at different depths in the ground and at the outlet of the ground heat exchanger.

14/02752 Experimental performance analysis of a direct-expansion ground source heat pump in Xiangtan, China

Yang, W. *Energy*, 2013, 59, 334–339.

The direct-expansion ground source heat pump (DX GSHP), which uses a buried copper piping network through which refrigerant is circulated, is one type of ground source heat pump (GSHP). This study investigates the performance characteristics of a vertical U-bend direct-expansion ground source (geothermal) heat pump system (DX GSHPS) for both heating and cooling. Compared with the conventional ground-coupled heat pump (GCHP) system, the DX GSHP system is more efficient, with lower thermal resistance in the ground heat exchanger and a lower (higher) condensing (evaporating) temperature in the cooling (heating) mode. In addition, the system performance of the whole DX GSHP system is also higher than that of the conventional GCHP system. A DX GSHP system in Xiangtan, China with a U-bend ground heat exchanger 42 m deep with a nominal outside diameter of 12.7 mm buried in a water well was tested and analysed. The results showed that the performance of this system is very high. The maximum (average) coefficients of performance of the system were found to be 6.08 (4.73) and 6.32 (5.03) in the heating and cooling modes, respectively.

14/02753 Hot water generation for oil sands processing from enhanced geothermal systems: process simulation for different hydraulic fracturing scenarios

Hofmann, H. *et al. Applied Energy*, 2014, 113, 524–547.

The oil sands in northern Alberta, Canada, are home to one of the largest hydrocarbon deposits on Earth. Huge amounts of hot water – at around 50–60 °C – are needed for the current extraction procedure and processing technology. The current practice of obtaining water from the Athabasca River and heating it by the burning of natural gas creates severe economic and environmental costs. In fact, 6% of Canada's gas consumption is used for this purpose. As seen, the generation of huge amounts of fossil energy through oil sands extraction requires a substantial amount of fossil energy consumption (natural gas). Geothermal energy has the potential to significantly reduce natural gas consumption and greenhouse gas (GHG) emissions at competitive costs. This study investigates how and whether or not the required hot water can be generated from the granitic basement rocks beneath the oil sands mining areas near Fort McMurray, located in the north-east of Alberta. Hydraulic fracturing and resulting reservoir scenarios were simulated for different expected conditions in the region in order to find suitable fracturing strategies and conditions for an enhanced geothermal system (EGS). The simulations show that suitable fracturing treatments can increase the hydraulic performance of the system and that EGS heat generation can significantly reduce the environmental impact at comparable costs associated with the current processing technology. With this effort, significant reductions in GHG emissions and natural gas consumption can be achieved.

14/02754 In situ optimization methodology for the water circulation pumps frequency of ground source heat pump systems

Montagud, C. *et al. Energy and Buildings*, 2014, 68, 42–53.

This paper presents an experimental study of the influence of the water circulation pumps frequency at the indoor and outdoor loops in the overall system performance of a ground source heat pump monitored plant, and describes a three-step new methodology to optimize the system energy performance and obtain the values of the optimal frequencies when on/off regulation is employed. The first step consists of several experimental tests of pseudo-random sequence of frequency steps for both, internal and external circulation pumps, carried out during a single day. The second step is the characterization of the quasi-steady state system performance as a function of circulation pump frequencies. The final step consists of, by means of an analytical expression, the extrapolation of results to any partial load ratio, what allows finding the optimal frequency as a function of the instantaneous thermal load. The advantage of the proposed methodology is that it can be carried out on site and is able to consider the phenomena occurring at the heat pump and the ground source heat exchanger when the flow rates are varied. The methodology can be applied to any installation incorporating variable speed circulation pumps. Results indicate large energy savings potential for this kind of installation.

14/02755 Investigation of a coupled geothermal cooling system with earth tube and solar chimney

Yu, Y. *et al. Applied Energy*, 2014, 114, 209–217.

This paper is a systematic study of a coupled geothermal cooling system with an earth-to-air heat exchanger and a solar collector enhanced solar chimney. Experiments were conducted with an existing test facility in summer to evaluate the performance of the system, in terms of passive cooling capability, active cooling capability and soil thermal capability. Correspondingly, three different tests were carried out over 43 days, from a passive cooling mode to an active cooling mode, and then back to a passive cooling mode. The results show that the coupled geothermal system feasibly provides cooling to the facility in a natural operation mode free without using any electricity. The solar collector enhanced solar chimney can provide more airflow to the system during the daytime with a stronger solar intensity. The thermal sensation analysis based on predicted mean vote and predicted percentage of unsatisfied people indicates that the indoor air condition under the natural airflow stage was more acceptable in terms of thermal comfort than that of the forced airflow stage. The cooling capacity of the coupled system drops quickly after the one-week forced airflow test due to the underground soil temperature increase. It takes the soil over two weeks to fully recover from the thermal saturation after the forced air test. In addition, the underground soil temperature test results indicate that the underground heat dissipation in the horizontal level was greater than that in the vertical level. The findings suggest that a minimum level of control on the system and consideration on soil saturation is needed to further improve the overall performance.

14/02756 Modeling of a two-phase CO_2-filled vertical borehole for geothermal heat pump applications

Eslami-Nejad, P. *et al. Applied Energy*, 2014, 114, 611–620.

A numerical model has been developed to study the complex thermal behaviour of a CO_2-filled vertical geothermal borehole consisting of a long copper U-tube embedded in a solid material (grout). The model accounts for combinations of single- and two-phase fluid flow which may occur along the U-tube length. An explicit solution for fully coupled steady-state conservation equations of mass, momentum and energy is applied. The borehole is divided into small volume elements due to relatively significant changes in the thermophysical properties of the fluid. Borehole wall temperature variations as well as thermal interaction between tube sections are taken into account and the model predicts the fluid temperature, pressure and two-phase quality profiles. A case in which the borehole is assumed to be an evaporator of a direct-expansion ground coupled heat pump is studied. The model is used to assess the thermal performance of the borehole as well as pressure, temperature and quality variations of CO_2 along the U-tube. According to the results, the pressure variation of the fluid in the two-phase region has unavoidable consequences on the temperature variation. Results indicate that the proposed borehole can extract relatively large amounts of energy due to the superior two-phase heat transfer characteristics of CO_2. Furthermore, the heat exchange rate between the ground and the upward flow leg in the two-phase region is greater than that between the ground and the downward flow, which is the opposite of conventional boreholes with a performance drop from the downward flow to the upward flow.

14/02757 Multi-source information fusion based fault diagnosis of ground-source heat pump using Bayesian network

Cai, B. *et al. Applied Energy*, 2014, 114, 1–9.

In order to increase the diagnostic accuracy of the ground-source heat pump (GSHP) system, especially for multiple-simultaneous faults, this paper proposes a multi-source information fusion-based fault diagnosis methodology using a Bayesian network. This is because it is considered to be one of the most useful models in the field of probabilistic knowledge representation and reasoning, and can deal with the uncertainty problem of fault diagnosis well. The Bayesian networks based on sensor data and information observed by human beings are established. Each Bayesian network consists of two layers: a fault layer and a fault symptom layer. The Bayesian network structure is established according to the cause and effect sequence of faults and symptoms, and the parameters are studied by using the Noisy-OR and Noisy-MAX models. The entire fault diagnosis model is established by combining the two proposed Bayesian networks. Six fault diagnosis cases of a GSHP system are studied, and the results show that the fault diagnosis model using the evidence from only the sensor data is accurate for single fault, while it is not accurate enough for multiple-simultaneous faults. By adding the observed information as evidence, the probability of a fault being present for single fault of 'refrigerant overcharge' increases to 100% from 99.69%, and the probabilities of a fault bring present for multiple-simultaneous faults of 'non-condensable gas' and 'expansion valve port enlargement' increases to almost 100% from 61.1% and 52.3%, respectively. In addition, the observed information can correct the wrong fault diagnostic results, such as 'evaporator fouling'. Therefore, the multi-source information fusion-based fault diagnosis model using a Bayesian network can increase the fault diagnostic accuracy greatly.

14/02758 Numerical investigation of fluid flow and heat transfer in a doublet enhanced geothermal system with CO_2 as the working fluid (CO_2–EGS)

Luo, F. *et al. Energy*, 2014, 64, 307–322.

An enhanced geothermal system with CO_2 instead of water as the working fluid (CO_2–EGS) has attracted much interest due to the additional benefit of CO_2 geological storage during the power generation process. This paper describes numerical analyses of a doublet CO_2–EGS system, focusing on the influence of the CO_2 injection rate, the permeability of induced fractures near the wellbores, the injection/production well perforation placement, the working fluid, and the heat transfer between the wellbores and the surrounding reservoir. The larger permeability in the induced fractures around the wellbores allows the fluid to more easily flow through the reservoir up to a critical fracture permeability, with further increases of the fracture permeability further reducing the pressure loss a little but the cost is not worth the added benefit. Induced fractures around the wellbores result in little difference among different wellbores perforation locations in the reservoir. Increased CO_2 injection rates reduce the heat transfer between the wellbores and the surrounding reservoir so that this heat transfer can be neglected at large mass flow rates. With CO_2 as the working fluid, the CO_2 temperature decreases significantly going up the production well. This paper presents some important implications for CO_2–EGS system for further numerical studies as well as for practical projects.

14/02759 Performance analyses of geothermal organic Rankine cycles with selected hydrocarbon working fluids

Liu, Q. *et al. Energy*, 2013, 63, 123–132.

Organic Rankine cycles (ORC) are promising systems for the conversion of low-temperature geothermal energy into electricity. The thermodynamic performance of the ORC with a wet cooling system is analysed here using hydrocarbon working fluids driven by geothermal water from 100 to 150 °C and reinjection temperatures of not less than 70 °C. The hydrocarbon working fluids are butane (R600), isobutane (R600a), pentane (R601), isopentane (R601a) and hexane. For each fluid, the ORC net power output first increases and then decreases with increasing turbine inlet temperature. The turbine inlet parameters are then optimized for the maximum power output. The ORC net power output increases as the condensation temperature decreases but the circulating pump power consumption increases especially for lower condensation temperatures at higher cooling water flow rates. The optimal condensation temperatures for the maximum plant power output are 29.45–29.75 °C for a cooling water inlet temperature of 20 °C and a pinch point temperature difference of 5 °C in the condenser. The maximum power is produced by an ORC using R600a at geothermal water inlet temperatures higher than 120 °C, followed by R245fa and R600 for reinjection temperatures not less than 70 °C. R600a also has the highest plant exergetic efficiency with the lowest turbine size factor.

14/02760 Performance assessment of a simplified hybrid model for a vertical ground heat exchanger

Maestre, I. R. *et al. Energy and Buildings*, 2013, 66, 437–444.

A simplified model to simulate single U-tube ground heat exchangers is presented in this paper. The model is based on the electrical analogy to simulate heat transfer within the borehole and the use of thermal response factors (g-functions) to estimate injection–extraction heat flow to surrounding ground. The inclusion of two capacities for the heat carrier fluid and the grout material makes the model suitable for short time-step simulations. The thermal resistance of the borehole has been changed considering different heat conduction paths. Several variants of the model have been validated through comparison with a refined computational fluid dynamic reference model. Good results have been obtained for the different variables analysed (outlet temperature and surface borehole temperature). Root mean squared error values were smaller than 1 °C while relative errors were <5%.

14/02761 Strategic use of the underground in an energy mix plan: synergies among CO_2, CH_4 geological storage and geothermal energy. Latium Region case study (central Italy)

Procesi, M. *et al. Applied Energy*, 2013, 110, 104–131.

The worldwide demand for energy has been increasing in recent decades with an associated rise in CO_2 emissions. In such conditions, the development of low-carbon energy technologies and strategic energy-mix plans is necessary, and an evaluation of the underground energy potential may be a useful step in developing these plans. This evaluation involves the synergic development of such technologies as coal combustion in combination with CO_2 geological storage (CCS), natural gas geological storage (CH_4-GS) and geothermal energy (GE), especially in densely populated countries such as Italy. Currently, 13.7% of Italian energy demand is met by foreign providers. Most of the Italian regions have energy deficits, and the Latium Region (in central Italy) represents one of those in the worst conditions. This work proposes a methodology to develop energy-mix scenarios, starting in Latium, to identify areas that are potentially suitable for CCS, CH_4-GS and GE. Six geothermal systems and one CO_2/CH_4 storage potential area were identified. Three main scenarios were proposed: (A) a combination of CH_4-GS with methane as cushion gas and GE; (B) a combination of CH_4-GS with CO_2 as cushion gas and GE and (C) a combination of CCS and GE. Scenario A results in a reduction of the regional energy deficit ranging from 21.8% to 45.6%. In Scenario B, the regional energy deficit reduction ranges from 30.8% to 80.7% and the CO_2 emissions reduction ranges from 1.4% to 5.6%, supposing an injection of 20 years. Scenario C shows a decrease in the regional energy deficit that ranges from 15.9% to 22.1%, while the CO_2 emissions reduction ranges from 7.1% to 31.3%, over the same time period. The proposed scenarios may be useful not only for the scientific community but also for policymakers as they identify the most reliable energetic strategies. Thus, this case study could be extended to the whole of Italy with the ultimate goal of reaching energy autonomy in each region.

14/02762 Stratigraphy and structure of the Ngatamariki geothermal system from new zircon U–Pb geochronology: implications for Taupo Volcanic Zone evolution

Chambefort, I. *et al. Journal of Volcanology and Geothermal Research*, 2014, 274, 51–70.

Recent drilling at the Ngatamariki Geothermal Field, Taupo Volcanic Zone, New Zealand has provided new constraints on the stratigraphy and volcanic evolution of the region. Over 2800 m thickness of volcanic products are present at Ngatamariki, mainly comprised of rhyolitic ignimbrites linked to large caldera-forming events at sources outside the field area, but locally sourced andesite and rhyolite lavas and domes are also encountered. Most of the rocks are allocated to the pre-0.35 Ma Tahorakuri Formation. Crystallisation age spectra (and consequent best estimates of eruption age) have been obtained by U–Pb dating on zircons from otherwise severely hydrothermally altered magmatic rocks by Secondary Ion Mass Spectrometry techniques using a SHRIMP-RG instrument. The oldest rock dated is an ignimbrite, which yields an eruption age estimate of 1.85 ± 0.06 Ma. This ignimbrite, plus comparable-aged units dated at the adjacent Rotokawa and Ohaaki geothermal fields, are interpreted to represent the oldest silicic volcanic deposits in the area, and onlap the basal andesite lava pile that is best developed at Rotokawa to the south. Other pyroclastic units and associated volcaniclastic sediments (with another intercalated andesite lava unit) return age estimates between 1.85 ± 0.06 and 0.701 ± 0.039 Ma. Between ~0.7 and 0.35 Ma, contemporaneous surface lithologies in the Ngatamariki area are dominated by sediments, with subordinate lava domes. Between 0.716 ± 0.017 and 0.655 ± 0.016 Ma at least three shallow (to < 2 km depth) intrusions were emplaced under the northern part of the field: a diorite, microdiorite and a large tonalite body totalling > 5 km^3. The intrusions generated a large alteration halo (~25 km^3 minimum) and intense silicification of the wall rocks. At 0.35 and 0.34 Ma the area was buried by two ignimbrite packages of the Whakamaru Group, erupted from sources just west and well north, respectively, of the field. Ignimbrites of the Waiora Formation and several rhyolite lava domes were then emplaced over a period bracketed by domes dated at 0.282 ± 0.011 and 0.257 ± 0.011 Ma, coeval with more extensive volcanic activity in the Maroa dome complex west of the field. Sediments of the Huka Falls Formation and deposits of the 25.4 ± 0.2 ka Oruanui eruption then cap and seal the system. The new U–Pb data coupled with detailed petrographical studies allow us to build the history of the area encompassed by the Ngatamariki Geothermal Field. The field, despite > 2.8 km of subsidence, does not lie in a caldera and is the only one known to date to have a plutonic intrusive complex of Quaternary age. Two chemically and temporally distinct hydrothermal events are located at the Ngatamariki field, with no evidence of continuity between the two.

14/02763 Studies on geothermal power generation using abandoned oil wells

Cheng, W.-L. *et al. Energy*, 2013, 59, 248–254.

In this paper, abandoned ‘dry hole’ oil wells are simulated as a source of geothermal power for generating electricity. Isobutane is chosen as the working fluid. It is heated by the geothermal energy from geologic formation and drives the turbine to generate electricity. A model based on transient formation heat transfer is presented. Furthermore, a numerical simulation for an abandoned well with a depth of 6000 m is performed. The result shows that the outlet temperature of fluid leaving the recovery well gradually decreases with the system operating time increasing and ultimately approaches stability. The stabilized time of the system can be shortened by either the increasing formation thermal conductivity or the decreasing inlet velocity of fluid entering the injection well but is not significantly influenced by the formation heat capacity. The net power depends on the total obtained heat and the outlet temperature of fluid leaving the recovery well. And increasing the inlet velocity can increase the total obtained heat but lower the fluid outlet temperature. Consequently there is an optimal inlet velocity of fluid entering the injection well to maximize the net power for a specified geothermal heat source.

14/02764 Studying effect of heating plant parameters on performances of a geothermal-fuelled series cogeneration plant based on organic Rankine cycle

Habka, M. and Ajib, S. *Energy Conversion and Management*, 2014, 78, 324–337.

This work aims to analyse the performance characteristics of the series combined heat and power (CHP) system based on an organic Rankine cycle (ORC) under the influence of heating plant parameters without considering the chemistry of the geothermal water as heat source. For evaluation, energetic and exergetic criteria along with the heat transfer capacities have been determined, and also the working fluid R134a has been used. The results showed that increasing the heat demand or the return temperature and only the high supply temperatures lead to stop the net power generated by the ORC–CHP system. The influence of these parameters on the total exergy efficiency and losses is different. Whereas raising the heat demands optimizes these exergetic indicators, variation of the supply temperature leads to an optimum for these performances. Since increasing the return temperature has purely negative impacts on all exergetic and energetic criteria, the latter can be improved by reducing this temperature with attention to the heat transfer capacities. Thus, reduction of the return temperature by about 5 °C lowers the exhaust stream losses by about 25% and enhances the power generation by about 52% and the total exergy efficiency by 9%.

14/02765 Temperature distribution in a field of long borehole heat exchangers (BHEs) subjected to a monthly averaged heat flux

Zanchini, E. and Lazzari, S. *Energy*, 2013, 59, 570–580.

A method to evaluate the long-term temperature distribution in a field of long borehole heat exchangers (BHEs) subjected to a monthly averaged heat flux is presented, under the assumption that the effects of the groundwater flow are negligible. Each BHE is considered as a cylindrical heat source with diameter D and length L. For each ratio L/D and dimensionless radial distance r/D, the *g-function* (time-dependent dimensionless temperature, averaged along the BHE length, due to a uniform and constant heat load) is determined by finite-element simulations and written in polynomial form through accurate interpolations, in a very broad range of values of the dimensionless time. Tables of the coefficients of the polynomial functions are provided. The *g*-functions are then used to determine the time evolution of the mean dimensionless temperature at the interface BHE-ground, averaged among BHEs, for some BHE fields subjected to a monthly averaged heat load.

14/02766 Thermal capacity effects in borehole ground heat exchangers

Shirazi, A. S. and Bernier, M. *Energy and Buildings*, 2013, 67, 352–364.

A one-dimensional transient ground heat exchanger model is proposed to account for fluid and grout thermal capacities in borehole ground heat exchangers with the objective of predicting the outlet fluid temperature for varying inlet temperatures and flow rates. The standard two-pipe configuration is replaced with an equivalent geometry consisting of a single pipe and a cylinder core filled with grout. Transient radial heat transfer in the grout is solved numerically while the ground outside the borehole is treated analytically using the cylindrical heat source method. The proposed model is validated successfully against analytical solutions, experimental data, a three-dimensional transient numerical model and TRNSYS's Type 451. For a typical two-pipe configuration, it is shown that the fluid outlet temperature predicted with and without borehole thermal capacity differs by 1.4, 0.35 and 0.23 °C after 0.1, 0.2 and 1 h, respectively. Annual simulations are also performed over an entire heating season (5600 h) with a 6-min time step. Results show that the outlet fluid temperature is always higher when borehole thermal capacity is included. Furthermore, the difference in fluid outlet temperature prediction with and without borehole thermal capacity increases when the heat pump operates infrequently. The end result is that the annual coefficient of performance predicted is approximately 4.5% higher when borehole thermal capacity is included.

14/02767 Thermal performance and economic evaluation of double U-tube borehole heat exchanger with three different borehole diameters

Luo, J. *et al. Energy and Buildings*, 2013, 67, 217–224.

This paper presents the results from an experimental study of borehole heat exchangers (BHE) installed in a ground source heat pump (GSHP) system in Nuremberg, Germany. The BHE was constructed with 18 boreholes that can be grouped into three blocks: block I of 121 mm, block II of 165 mm and block III of 180 mm. The operation of the GSHP system had been monitored between March 2009 and October 2012 for analysis. Over the years of the system's operation, the thermal performance of BHEs was observed to be slightly improved for larger borehole diameters (blocks II and III). For the comparison among the three blocks, thermal loads of block II is 1.64% and block III is 3.45% larger than that of block I, respectively. Furthermore, saving-to-investment ratio (SIR) is evaluated for two parts: the basic part (SIR_{I}) for block I; the extra parts ($SIR_{II–I}$, $SIR_{III–I}$) for block II and block III. Over a 30-year period, the SIR is estimated to be 4.80, 2.14 and 3.18 for SIR_{I}, SIR_{II-I} and SIR_{III-I}, respectively. These findings suggest that block I has the highest economic profitability. Based on these evaluations, the acceptable drilling costs for blocks II and III are also analysed and discussed.

14/02768 Thermal response test and numerical analysis based on two models for ground-source heat pump system

Yu, X. *et al. Energy and Buildings*, 2013, 66, 657–666.

The thermal response test is becoming increasingly popular in obtaining the ground thermal properties as well as evaluating the performance of the ground heat exchanger that determines the properties of ground source heat pump system. This study investigated a practical engineering project, which is located in Shijiazhuang, Hebei Province, China, as an example to test the ground thermal properties. A popular constant heating-flux method was used with the heat load of 3.6 and 8.4 kW, respectively. This investigation compared and analysed the ground thermal properties by the line source model and the cylinder source model. This study also conducted the sensitivity analysis on different data intervals by fixing starting time or ending time. Moreover, a new method (Bland–Altman analysis) was proposed to analyse and determine the agreement between simulated and experimental data. The results showed that the new method performed well in evaluating the agreement and could help to properly choose the test duration and data interval for thermal response test.

14/02769 Thermodynamic and economic analysis and optimization of power cycles for a medium temperature geothermal resource

Coskun, A. *et al. Energy Conversion and Management*, 2014, 78, 39–49.

Geothermal power generation technologies are well established and there are numerous power plants operating worldwide. Turkey is rich in geothermal resources while most resources are not exploited for power production. This study considers geothermal resources in the Kutahya–Simav region having geothermal water at a temperature suitable for power generation. The study is aimed to yield the method of the most effective use of the geothermal resource and a rational thermodynamic and economic comparison of various cycles for a given resource. The cycles considered include double-flash, binary, combined flash/binary and Kalina cycle. The selected cycles are optimized for the turbine inlet pressure that would generate maximum power output and energy and exergy efficiencies. The distribution of exergy in plant components and processes are shown using tables. Maximum first law efficiencies vary between 6.9% and 10.6% while the second law efficiencies vary between 38.5% and 59.3% depending on the cycle considered. The maximum power output, the first law, and the second law efficiencies are obtained for Kalina cycle followed by combined cycle and binary cycle. An economic analysis of four cycles considered indicates that the cost of producing a unit amount of electricity is $0.0116/kW h for double flash and Kalina cycles, $0.0165/kW h for combined cycle and $0.0202/kW h for binary cycle. Consequently, the payback period is 5.8 years for double flash and Kalina cycles while it is 8.3 years for combined cycle and 9 years for binary cycle.

14/02770 Thermodynamic and economic evaluations of a geothermal district heating system using advanced exergy-based methods

Tan, M. and Keçebaş, A. *Energy Conversion and Management*, 2014, 77, 504–513.

In this paper, a geothermal district heating system (GDHS) is comparatively evaluated in terms of thermodynamic and economic aspects using advanced exergy-based methods to identify the potential for improvement, the interactions among system components, and the direction and potential for energy savings. The actual operational data are taken from the Sarayköy GDHS, Turkey. In the advanced exergetic and exergoeconomic analyses, the exergy destruction and the total operating cost within each component of the system are split into endogenous/exogenous and unavoidable/avoidable parts. The advantages of these analyses over conventional ones are demonstrated. The results indicate that the advanced exergy-based method is a more meaningful and effective tool than the conventional one for system performance evaluation. The exergetic efficiency and the exergoeconomic factor of the overall system for the Sarayköy GDHS were determined to be 43.72% and 5.25% according to the conventional tools and 45.06% and 12.98% according to the advanced tools. The improvement potential and the total cost-savings potential of the overall system were also determined to be 2.98% and 14.05%, respectively. All of the pumps have the highest improvement potential and total cost-savings potential because the pumps were selected to have high power during installation at the Sarayköy GDHS.

14/02771 Thermoeconomic optimization of vertical ground-source heat pump systems through nonlinear integer programming

Retkowski, W. and Thöming, J. *Applied Energy*, 2014, 114, 492–503.

Vertical ground-source heat pump systems (GSHPSs) use the ground's undisturbed relative constant temperature as a source for space heating of residential and commercial buildings. The design of GSHPSs is focused in finding the optimal depth and amount of boreholes and also the connected power requirement like the amount and size of heat pumps. In this paper a mixed-integer non-linear programming (MINLP) approach to solve the design problem of a vertical GSHPS is presented. The resulting mathematical model includes the calculation of the total annual costs (TAC) and the coefficient of performance to obtain estimates of both economic and ecological relevance to design an optimal equipment set-up. For desired constraints the numerically optimal values of the design parameters (borehole depth, mass flow rate, number of boreholes, type and number of the heat pumps) were calculated. Two numerical solution alternatives are investigated, namely the generalized reduced gradient (GRG2) and the evolutionary algorithm. The GRG2 approach provides a more stable and faster optimal solution. Calculated results are presented through a validation example. The evaluation of the proposed objectives and studied sensitivity effects present the applicability of the model. This method was able to improve the TAC about more than 10%.

14/02772 Three heating seasons monitoring of thermo-economic parameters of a prototype EAHE system for technological forecasting and evaluating low grade geothermal resources in Turkey

Ozgener, L. and Ozgener, O. *Energy and Buildings*, 2013, 66, 346–352.

The design and analysis of earth to air heat exchanger (EAHE) systems are based on well-established engineering knowledge. This paper monitors thermoeconomic parameters of a prototype EAHE system. The relations between capital costs and thermodynamic losses for the devices in the system are investigated and the results presented. The concept of EAHE is not new, however their use in residential and agricultural buildings is new in Turkey, although they have been in use for years in developed countries and the performance of the components is well documented. The authors found that the majority of the installations can be applied in all regions of Turkey for evaluating low-grade geothermal resources.

14/02773 Types of the scaling in hyper saline geothermal system in northwest Turkey

Demir, M. M. *et al. Geothermics*, 2014, 50, 1–9.

Tuzla is an active geothermal area located in north-western Turkey, 80 km south of the city of Canakkale and 5 km from the Aegean coast. The geothermal brine from this area, which is dominated by NaCl, has a typical temperature of 173 °C. Rapid withdrawal of fluid to ambient surface conditions during sampling causes precipitation of various compounds known as scaling. Scaling is one of the important problems in Tuzla geothermal system that reduces the efficiency of the geothermal power plant and causes economical loss. The aim of this study was to determine the type of scaling as a first step towards preventing its formation. The scales formed in the geothermal system were divided into two groups according to location: the ones that formed in downhole and the ones that accumulated along the surface pipeline. Both scales were examined in terms of their elemental composition, structure and morphology using X-ray fluorescence, X-ray diffraction and scanning electron microscopy, respectively. The former was found to be mainly composed of PbS (Galena) and $CaCO_3$ (aragonite or calcite). In contrast, the latter was heterogeneous in nature and consisted of mainly saponite like amorphous structure along with submicrometre-sized amorphous silica particles, layered double magnesium and iron hydroxide, and NaCl.

Solar energy

14/02774 A comparative study of three types of grid connected photovoltaic systems based on actual performance

Ya'acob, M. E. *et al. Energy Conversion and Management*, 2014, 78, 8–13.

In this study, three photovoltaic (PV) systems are evaluated based on actual performance. The energy generation of three types of PV systems namely a concentrating PV system (6 units × 1 kWp), a PV system with sun tracking flat (2 units × 1 kWp) and a fixed flat PV system (2 units × 1 kWp) is analysed in this research. Data analysis for 10 consecutive months consisting of 12,190 samples of 15-min intervals is carried out. The performance evaluation is done using energy yield, yield factor, capacity factor, power efficiency and PV array efficiency. Based on the experiment data, it is concluded that the tracking flat PV system is the most suitable system for Malaysia in a normal operation mode with an average daily generation of 4.7 kW h (141 kW h as a monthly average), system efficiency of 11%, power efficiency of 85%, average daily yield factor of 2.3 kW h/kWp and capacity factor of 32%. This study also highlights the PV energy (E_{PV}) models for each PV generators with respect to the environmental factors. The advantage of employing a tracking flat system as compared to the fixed flat system is considered based on the effectiveness of the dual-axis tracking mechanism tracking the sun for maximum power output.

14/02775 A comparison of three test methods for determining the thermal performance of parabolic trough solar collectors

Xu, L. *et al. Solar Energy*, 2014, 99, 11–27.

Based on the theoretical background and experimental results, a study on the extensive comparison of three outdoor test methods for determining the thermal performance of parabolic trough solar collectors is presented. These test methods are the steady-state method in the ASHRAE 93 standard, the quasi-dynamic method in the EN 12975–2 standard and a new dynamic method developed elsewhere. They are discussed in detail and are explained in view of the on-site parabolic trough solar collectors in the real service. In addition, the experimental data acquired from four typical test cases at the transient working conditions is applied to obtain the parameters of three mathematical models in the test methods and predict the collector outlet temperature, and collector output power. Furthermore, the comparative analysis on the projections of the essential thermal performance indicators shows the advantages and disadvantages of these three test models according to both the practical operation and weather conditions, which proves that the dynamic model may be the potential core of a quick, reliable on-site thermal performance test method at some future time.

14/02776 A linear piezoelectric actuator based solar panel cleaning system

Lu, X. *et al. Energy*, 2013, 60, 401–406.

A linear piezoelectric actuator based solar panel cleaning system is proposed in order to make a solar panel operate at the best power generation state while the solar panel is used in dusty environment. A piezoelectric actuator linearly moving on a guide is employed to drive a wiper fixed on the actuator. At a proper pressure force between the wiper and solar panel, the actuator can drive the wiper to effectively wipe a dust layer away from the solar panel's surface. The cleaning system's energy gain, which is defined as the ratio of a solar panel's output electric energy increase caused by cleaning to the energy consumption by the piezoelectric actuator, is much higher than 1. The merits of using the piezoelectric actuator in a solar panel cleaning system is that the cleaning system has light weight and compact structure, which is a common feature of piezoelectric systems.

14/02777 A simplified model for the estimation of energy production of PV systems

Aste, N. *et al. Energy*, 2013, 59, 503–512.

The potential of solar energy is far higher than any other renewable source, although several limits exist. In detail the fundamental factors that must be analysed by investors and policy makers are the cost-effectiveness and the production of photovoltaic (PV) power plants, respectively, for the decision of investment schemes and energy policy strategies. Tools suitable to be used even by non-specialists, are therefore becoming increasingly important. Many research and development effort have been devoted to this goal in recent years. In this study, a simplified model for PV annual production estimation that can provide results with a level of accuracy comparable with the more sophisticated simulation tools from which it derives is fundamental data. The main advantage of the presented model is that it can be used by virtually anyone, without requiring a specific field expertise. The inherent limits of the model are related to its empirical base, but the methodology presented can be effectively reproduced in the future with a different spectrum of data in order to assess, for example, the effect of technological evolution on the overall performance of PV power generation or establishing performance benchmarks for a much larger variety kinds of PV plants and technologies.

14/02778 A system-level cost-of-energy wind farm layout optimization with landowner modeling

Chen, L. and MacDonald, E. *Energy Conversion and Management*, 2014, 77, 484–494.

This work applies an enhanced levelized wind farm cost model, including landowner remittance fees, to determine optimal turbine placements under three landowner participation scenarios and two land-plot shapes. Instead of assuming a continuous piece of land is available for the wind farm construction, as in most layout optimizations, the problem formulation represents landowner participation scenarios as a binary string variable, along with the number of turbines. The cost parameters and model are a combination of models from the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory, and Windustry. The system-level cost-of-energy (COE) optimization model is also tested under two land-plot shapes: equally sized square land plots and unequal rectangle land plots. The optimal COEs results are compared to actual COE data and found to be realistic. The results show that landowner remittances account for approximately 10% of farm operating costs across all cases. Irregular land-plot shapes are easily handled by the model. It was found that larger land plots do not necessarily receive higher remittance fees. The model can help site developers identify the most crucial land plots for project success and the optimal positions of turbines, with realistic estimates of costs and profitability.

14/02779 Active power estimation of photovoltaic generators for distribution network planning based on correlation models

Ramon-Marin, M. *et al. Energy*, 2014, 64, 758–770.

Photovoltaic (PV) generation has had an impact on low- and medium-voltage grids in Spain due to the increasing number of installations. As power monitoring of the generation is in most cases not required, utilities are forced to make assumptions on PV power generation in order to perform network planning studies for both peak demand and contingency analysis. These assumptions increase errors committed during the analysis, as the number of PV installations increases. This paper presents a methodology for estimating PV active power generation values for planning purposes in medium- and low-voltage power systems, from historic generation data, based on the development of correlation models. This methodology is applied to three different examples using predictors based on real registered data. The methodology was also applied in a typical grid study and its error was determined.

14/02780 Bio-oil production via co-pyrolysis of almond shell as biomass and high density polyethylene

Önal, E. *et al. Energy Conversion and Management*, 2014, 78, 704–710.

Biomass from almond shells (aS) was co-pyrolysed with high-density polyethylene (HDPE) polymer to investigate the synergistic effects on the product yields and compositions. The pyrolysis temperature was selected as 500 °C, based on results of a thermogravimetric and differential thermal analysis. Co-pyrolysis of HDPE–biomass mixtures were pyrolysed with various proportions such as 1 : 0, 1 : 1, 1 : 2, 2 : 1 and 0 : 1. The yield of liquids produced during co-pyrolysis enhanced 23%, as the weight ratio of HDPE in the mixture was doubled. Obtained bio-oils were analysed with using column chromatography, ^{1}H nuclear magnetic resonance, gas chromatography–mass spectrometry and Fourier transform infrared spectroscopy. According to analyses results, produced liquids by co-pyrolysis had higher carbon (26% higher) and hydrogen contents (78% higher), lower oxygen content (%86 less) with a higher heating value (38% higher) than those of biomass oil.

14/02781 Classification of methods for annual energy harvesting calculations of photovoltaic generators

Rus-Casas, C. *et al. Energy Conversion and Management*, 2014, 78, 527–536.

Estimating the energy provided by the generators of grid-connected photovoltaic (PV) systems is important in order to analyse their economic viability and supervise their operation. The energy harvesting calculation of a PV generator is not trivial; there are many methods for this calculation. The aim of this paper is to develop a novel classification of methods for annual energy harvesting calculation of a generator of a grid-connected PV system. The methods are classified in two groups: (1) those that indirectly calculate the energy, i.e. they first calculate the power and from this, they calculate the energy, and (2) those that directly calculate the energy. Furthermore, the indirect methods are grouped in two categories: those that first calculate the *I*–*V* curve of the generator and from this, they calculate the power, and those that directly calculate the power. The study has shown that the existing methods differ in simplicity and accuracy, so that the proposed classification is useful in order to choose the most suitable method for each specific application.

14/02782 Comprehensive monitoring of a biogas process during pulse loads with ammonia

Bruni, E. *et al. Biomass and Bioenergy*, 2013, 56, 211–220.

A thermophilic pilot-scale anaerobic digester treating chicken litter was subjected to pulse loads of ammonia of increasing concentration. A micro-gas-chromatograph measured CO_2, CH_4, N_2, H_2 and H_2S in the biogas. In the liquid, NH_4-N was measured manually, volatile fatty acids (VFA) were measured manually and with near infrared spectroscopy (NIRS). Within the first 7–24 h after the pulse, the concentrations of iso-butyric and iso-valeric acid increased rapidly and were the best indicators of process stress due to ammonia pulses, confirmed by multivariate analysis. NIRS was not capable of accurate prediction of VFA iso-forms most likely due to low concentrations. Propionic acid was persistent. The ammonia pulses caused an overall decrease of biogas production. The biogas composition was not a good indicator of imbalances; little correlation with VFA measurements was observed.

14/02783 Economic and energy analysis of three solar assisted heat pump systems in near zero energy buildings

Thygesen, R. and Karlsson, B. *Energy and Buildings*, 2013, 66, 77–87.

The European Union's directive on the energy performance of buildings makes energy systems with local energy generation interesting. To support local energy generation, the government has appointed a commission to investigate the possibility of implementing net metering for grid connected photovoltaic (PV)-systems. In this paper, three different systems are simulated and analysed with regards to economics and energy: a PV-system and a heat pump (alternative 1), a heat pump and a solar thermal system (alternative 2) and a heat pump, a PV-system and a solar thermal system (alternative 3). System alternative 1 is profitable with daily net metering and monthly net metering and unprofitable with instantaneous net metering. The solar electrical fraction of the system is 21.5%, 43.5% and 50%, respectively. System alternative 2 is unprofitable and has a solar electricity fraction of 5.7%. System alternative 3 is unprofitable and has a solar electricity fraction of just below 50. The conclusion is that a PV system in combination with a heat pump is a superior alternative to a solar thermal system in combination with a heat pump.

14/02784 Effects of evaporative cooling on efficiency of photovoltaic modules

Alami, A. H. *Energy Conversion and Management*, 2014, 77, 668–679.

The output decline of solar photovoltaic (PV) modules as their temperature increase during operation is a major concern for developers and users. This paper investigates the utilization of a passive evaporative cooling technique to control the temperature rise of PV modules that occurs due to the absorption of solar irradiance. The method involves incorporating a layer of synthetic clay to the back of the module and allowing a thin film of water to evaporate, and thus reducing the module temperature. The results have proven the technical feasibility of the proposed approach by exhibiting a maximum increase of 19.4% to the output voltage and 19.1% to the output power. The incorporation of clay is very effective, cheap, silent and environmentally friendly.

14/02785 Efficiency analysis of a multi-fuzzy logic controller for the determination of operating points in a PV system

Rajesh, R. and Carolin Mabel, M. *Solar Energy*, 2014, 99, 77–87.

Photovoltaic power characteristics have multiple local and global maximum power operating points due to non-linear solar insolation. To track the operating point exactly, suitable algorithm is needed. In this paper, a new multi-fuzzy logic based maximum power point tracking controller is proposed and the tracking performance is examined with one-day solar insolation data. The proposed algorithm follows current control for better performance of the converter. The output of the proposed method, that is the reference current, controls the DC–DC boost converter as per the changes of photovoltaic power, voltage, and converter duty cycle. Implementation is done in MATLAB/Simulink and the PV power is evaluated and its characteristics are compared. The comparative analysis with fuzzy logic controller and a perturb and observe algorithm shows that, the proposed controller takes less time to settle at the maximum power operating point, eliminated oscillation around the operating point and also reduced the steady state error by 1.29% and 1.76%, respectively.

14/02786 Enhanced optical absorption of the plasmonic nanoshell suspension based on the solar photocatalytic hydrogen production system

Duan, H. and Xuan, Y. *Applied Energy*, 2014, 114, 22–29.

The absorption properties of the random Al/CdS nanoshell systems are simulated using the finite difference time domain method. The interactions between the nanoshells have been taken into account in the simulation. By comparing the optical absorption of dispersion system with that of single nanoshell, it reveals that the inter-particle coupling cannot be neglected in the simulation of dispersion system. The absorption enhancement is affected by both the inter-particle coupling and the localized surface plasmon resonance effect. The dispersed nanoparticles induce longer optical path inside the dispersion system and enhance light trapping as well as absorption. It can be considered to increase the nanoshell concentration and reduce the particle size to obtain an enhanced absorption.

14/02787 Enhancement of modified solar still integrated with external condenser using nanofluids: an experimental approach

Kabeel, A. E. *et al. Energy Conversion and Management*, 2014, 78, 493–498.

The distilled water productivity of the single basin solar still is very limited. In this context, the design modification of a single basin solar still has been investigated to improve the solar still performance through increasing the productivity of distilled water. The experimental attempts are made to enhance the solar still productivity by using nanofluids and also by integrating the still basin with external condenser. The used nanofluid is the suspended nanosized solid particles of aluminium oxide in water. Nanofluids change the transport properties, heat transfer characteristics and evaporative properties of the water. Nanofluids are expected to exhibit superior evaporation rate compared with conventional water. The effect of adding an external condenser to the still basin is to decrease the heat loss by convection from water to glass as the condenser acts as an additional and effective heat and mass sink. So, the effect of drawn vapour at different speeds was investigated. The results show that integrating the solar still with external condenser increases the distillate water yield by about 53.2%. And using nanofluids improves the solar still water productivity by about 116%, when the still integrated with the external condenser.

14/02788 Evaporation suppression and solar energy collection in a salt-gradient solar pond

Ruskowitz, J. A. *et al. Solar Energy*, 2014, 99, 36–46.

Evaporation represents a significant challenge to the successful operation of solar ponds. In this work, the suppression of evaporative losses from a salt-gradient solar pond was investigated in the laboratory. Two floating element designs (floating disks and floating hemispheres) and a continuous cover were tested; all three covers/elements were non-opaque, which is unique from previous studies of evaporation suppression in ponds or pools where increasing temperature and heat content are not desired. It was found that floating disks were the most effective element; full (88%) coverage of the solar pond with the floating disks decreases the evaporation rate from 4.8 to 2.5 mm/day (47% decrease), increases the highest achieved temperature from 34 to 43 °C (26% increase), and increases heat content from 179 to 220 MJ (22% increase). As a result of reduced evaporative losses at the surface, the amount of heat lost to the atmosphere is also reduced, which results in lower conductive losses from the non-convective zone (NCZ) and the lower convective zone (LCZ) and hence, increased temperatures in the NCZ and LCZ. The magnitude of evaporation reduction observed in this work is important as it may enable solar pond operation in locations with limited water supply for replenishment. The increase in heat content allows more heat to be withdrawn from the pond for use in external applications, which significantly improves the thermal efficiencies of solar ponds.

14/02789 Experimental validation of a theoretical model for a direct-expansion solar-assisted heat pump applied to heating

Moreno-Rodriguez, A. *et al. Energy*, 2013, 60, 242–253.

This paper discusses the experimental validation of a theoretical model that determines the operating parameters of a direct-expansion solar-assisted heat pump applied to heating. For this application, the model took into account the variable condensing temperature, and it was developed from the following environmental variables: outdoor temperature, solar radiation and wind. The experimental data were obtained from a prototype installed at the University Carlos III, which is located south of Madrid in Spain. The prototype uses a solar collector with a total area of 5.6 m^2, a compressor with a rated capacity of 1100 W, a thermostatic expansion valve and fan-coil units as indoor terminals. The monitoring results were analysed for several typical days in the climatic zone where the machine was located to understand the equipment's seasonal behaviour. The experimental coefficient of the performance varies between 1.9 and 2.7, and the equipment behaviour in extreme outdoor conditions has also been known to determine the thermal demand that can be compensated for.

14/02790 Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data

Islam, T. *Energy Policy*, 2014, 65, 340–350.

This study focuses on predicting the adoption time probabilities of photovoltaic solar panels by households using discrete choice experiments and an innovation diffusion model. The primary objective of this research is cohesively mapping the theory of disruptive innovation into diffusion of innovations to aid policy makers by linking two critical uncertainties of new technology: (1) whether households prefer the new attributes of the new technology and how these preferences vary by market segments? and (2) when are they going to adopt (if at all)? This study uses recent developments of discrete choice experiments and establishes a causal link between the attributes of the technology, attitudinal constructs and socio-demographics, and adoption time probabilities using the Bass diffusion model. The data were collected from Ontario, a province of Canada. The innovation diffusion model allows us to compute the cumulative probability of adoption over time per household. Technology awareness and energy cost saving have a significant effect on the adoption probability, reinforcing the need for effective education. These findings also suggest that campaigns should explain more about investment criteria, feed-in tariffs and environmental attributes. This study findings call for a need to use seeding strategies to accelerate exogenous word-of-mouth for this new technology.

14/02791 Integral energy performance characterization of semi-transparent photovoltaic elements for building integration under real operation conditions

Olivieri, L. *et al. Energy and Buildings*, 2014, 68, 280–291.

In this paper, a methodology for the integral energy performance characterization (thermal, daylighting and electrical behaviour) of semi-transparent photovoltaic modules (STPV) under real operation conditions is presented. An outdoor testing facility to analyse simultaneously thermal, luminous and electrical performance of the devices has been designed, constructed and validated. The system, composed of three independent measurement subsystems, has been operated in Madrid with four prototypes of a-Si STPV modules, each one corresponding to a specific degree of transparency. The extensive experimental campaign, continued for a whole year rotating the modules under test, has validated the reliability of the testing facility under varying environmental conditions. The thermal analyses show that both the solar protection and insulating properties of the laminated prototypes are lower than those achieved by a reference glazing whose characteristics are in accordance with the Spanish building code. Daylighting analysis shows that STPV elements have an important lighting energy saving potential that could be exploited through their integration with strategies focused to reduce illuminance values in sunny conditions. Finally, the electrical tests show that the degree of transparency is not the most determining factor that affects the conversion efficiency.

14/02792 Modeling and simulation for the design of thermal-concentrated solar thermoelectric generator

Chen, W.-H. *et al. Energy*, 2014, 64, 287–297.

The performance of thermal-concentrated solar thermoelectric generators (TEGs) at three different geometric types is investigated numerically to aid in designing practical devices. The temperature-dependent properties of the commercial thermoelectric material are taken into account, and an equivalent model based on the three-dimensional finite element scheme is developed to simplify and accelerate simulations. The constriction thermal resistance and thermal spreading resistance are considered in the equivalent model. Increasing substrate area increases the thermal concentration ratio; this improves the performance of the solar TEG. In the three geometric types, the smallest element with the substrate area of $90 \times 90\,mm^2$ provides the maximum system efficiency of 4.15%. For a TEG at a given element length, decreasing the cross-sectional area of the thermoelectric element is a feasible route to improve the performance. Under the situation of forced convection, the varying convection heat-transfer coefficient has an ignorable effect on the performance. For equal convective heat-transfer coefficients, water cooling is better than air cooling for the net output power of the TEG because of its increased specific heat. Therefore, water cooling is recommended for the cooling of the solar TEG.

14/02793 Performance of grid-tied PV facilities: a case study based on real data

Díez-Mediavilla, M. *et al. Energy Conversion and Management*, 2013, 76, 893–898.

A new procedure is presented to analyse the performance of grid-tied photovoltaic (PV) facilities. It needs limited amounts of data that are easily sourced and is based on knowledge of the analysed system and its mode of operation. The procedure is applied, in a case study, to compare real PV production at two 100 kW_p grid-connected PV installations. Located in the same geographical region, the installation of these two facilities followed the same construction criteria – PV panels, panel support system and wiring – and the facilities were exposed to the same atmospheric temperature and solar radiation. They differ with regard to their inverter technology: one facility uses an inverter with an integrated transformer system and the other uses a transformerless inverter. The results show that the transformerless inverter system performed better than the isolated system by a factor of 1.2%, which, in economic terms, represents more than €2000/year.

14/02794 Single-phase three-wire grid-connected power converter with energy storage for positive grounding photovoltaic generation system

Shen, J.-M. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 134–143.

A single-phase three-wire grid-connected power converter with energy storage for positive grounding photovoltaic generation system (PGPGS) is proposed in this paper. The positive terminal of the solar cell array can be directly connected to the ground to avoid unexpected degradation of the special thin-film solar cell array. The proposed PGPGS consists of a solar cell array, two DC–DC power converters, a battery set, a switch set and a three-port power converter. The three-port power converter comprises a high-voltage DC port, a low-voltage DC port and an AC port. The solar cell array is connected to the high-voltage DC port through two DC–DC power converters whose positive terminal is directly connected to the ground. The battery set is connected to the low-voltage DC port, and the AC port is connected to the utility. No transformer is required in this PGPGS even when using the low-voltage battery set. A prototype is developed and tested to verify the performance of the PGPGS. The experimental results show that the proposed power converter has the expected performance.

14/02795 System-level simulation of a solar power tower plant with thermocline thermal energy storage

Flueckiger, S. M. *et al. Applied Energy*, 2014, 113, 86–96.

A thermocline tank is a low-cost thermal energy storage subsystem for concentrating solar power plants that typically utilizes molten salt and quartzite rock as storage media. Long-term thermal stability of the storage concept remains a design concern. A new model is developed to provide comprehensive simulation of thermocline tank operation at low computational cost, addressing deficiencies with previous models in the literature. The proposed model is then incorporated into a system-level model of a 100 MW_e power tower plant to investigate storage performance during long-term operation. Solar irradiance data, taken from measurements for the year 1977 near Barstow, California, USA, are used as inputs to the simulation. The heliostat field and solar receiver are designed with DELSOL, while the transient receiver performance is simulated with SOLERGY. A meteorological year of plant simulation with a 6-h capacity for the thermocline tank storage yields an annual plant capacity factor of 0.531. The effectiveness of the thermocline tank at storing and delivering heat is sustained above 99% throughout the year, indicating that thermal stratification inside the tank is successfully maintained under realistic operating conditions. Despite its good thermal performance, structural stability of the thermocline tank remains a concern due to the large thermal expansion of the internal quartzite rock at elevated molten-salt temperatures, and requires further investigation.

14/02796 Thermal performance of a solar storage packed bed using spherical capsules filled with PCM having different melting points

Yang, L. *et al. Energy and Buildings*, 2014, 68, 639–646.

In this paper, a packed bed heat storage system using spherical capsules filled with three kinds of phase change materials (PCMs) was presented and numerically studied. The capsules are filled into a packed bed which is connected with a flat plate solar collector. The capsules are placed in series based on the melting temperature of the PCM. Water is used as a heat transfer fluid (HTF) and heated in the solar collector. Solar energy is transferred to the PCM and preserved as latent thermal energy. The heat transfer processes of the HTF and the PCM capsules were modelled and numerically calculated using the finite difference method. The effective thermal conductivity of the liquid phase was used to take into account the effect of natural convection on the heat transfer during melting. The energy and exergy performances of the multiple-type packed bed were studied and compared with the performance of a single-type PCM packed bed. The performance of the solar collector was also investigated. The comparison results indicate that this new type of heat storage packed bed has higher energy and exergy transfer efficiencies than the traditional packed bed, and the average energy and exergy collection efficiency of its solar collector are higher as well.

14/02797 Thermal performance of a solar water heater with internal exchanger using thermosiphon system in Côte d'Ivoire

Koffi, P. M. E. *et al. Energy*, 2014, 64, 187–199.

This study presents a theoretical and experimental analysis of the thermal performance of a solar water heater prototype with an internal exchanger using thermosiphon system. The results focus mainly on the levels of the heat fluxes temperatures recorded, mass flow rate and efficiency of collector. These tests are performed for a sunny day and a cloudy day. The daily solar intensities range from 300 to 1233 W/m^2, with the daily ambient temperature ranging between 27 and 33 °C. Maximum temperatures at the flat solar collector output are 88 and 58 °C for the sunny day and cloudy day, respectively. Maximum instantaneous efficiencies are 68.33% and 50% for the sunny day and the cloudy day, respectively. The values of the thermal performances parameters $F_R\ (\tau\alpha)$ and $F_R U_L$ are 0.780 and 4.252 W/m^2 °C respectively for the cloudy day and 0.777 and 4.689 W/m^2 °C respectively for the sunny day. The coefficient of exchange thermal of heat exchanger U_e found is 149.15 W/(m^2 K) when, the average heat exchanger effectiveness obtained is 70%. The experimental results show that mean daily efficiency is near 50%. This reveals a good compatibility of the system to convert solar energy to heat which can be used for heating water.

14/02798 Tools and methods used by architects for solar design

Kanters, J. *et al. Energy and Buildings*, 2014, 68, 721–731.

Architects have a key role to play when it comes to the design of future low-energy (solar) buildings. Proper design tools and working methods could help architects in the design process. In order to identify barriers of existing tools and methods for solar design, needs of architects for improved tools, and to gain an insight into architects' methods of working during the design process, an international survey was carried out within the framework of IEA-SHC Task 41-Solar Energy and Architecture, combined with semi-structured interviews. This paper presents an overview of main results of this study. Both the survey and interviews strongly indicate the need for further development of design tools for solar architecture, focusing on a user-friendly, visual tool that is easily interoperable within current modelling software packages, and which generates clear and meaningful results that are compatible with the existing work flow of the architect. Furthermore, the survey and interviews also indicated a strong awareness about solar aspects among respondents. However, this was combined with a limited use and knowledge of solar energy technologies, suggesting the need for further skill development among architects and tool development to accelerate the implementation of these technologies in future buildings and urban fabric.

Wind energy

14/02799 A physical approach of the short-term wind power prediction based on CFD pre-calculated flow fields

Li, L. *et al. Journal of Hydrodynamics, Ser. B*, 2013, 25, (1), 56–61.

A physical approach of the wind power prediction based on the computational fluid dynamics (CFD) pre-calculated flow fields is proposed in this paper. The flow fields are obtained based on a steady CFD model with the discrete inflow wind conditions as the boundary conditions, and a database is established containing the important parameters including the inflow wind conditions, the flow fields and the corresponding wind power for each wind turbine. The power is predicted via the database by taking the numerical weather prediction (NWP) wind as the input data. In order to evaluate the approach, the short-term wind power prediction for an actual wind farm is conducted as an example during the period of the year 2010. Compared with the measured power, the predicted results enjoy a high accuracy with the annual root mean square error of 15.2% and the annual mean absolute error of 10.80%. A good performance is shown in predicting the wind power's changing trend. This approach is independent of the historical data and can be widely used for all kinds of wind farms including the newly built wind farms. At the same time, it does not take much computation time while it captures the local air flows more precisely by the CFD model. So it is especially practical for engineering projects.

14/02800 Assessment of wind power generation along the coast of Ghana

Adaramola, M. S. *et al. Energy Conversion and Management*, 2014, 77, 61–69.

This study examined the wind energy potential and the economic viability of using wind turbine for electricity generation in selected locations along the coastal region of Ghana. The two-parameter Weibull probability density function was employed to analyse the wind speed data obtained from the Ghana Energy Commission. The energy output and unit cost of electricity generated from medium-sized commercial wind turbine models with rated powers ranging from 50 to 250 kW were determined. It was found that the wind resource along the coastal region of Ghana can be classified into Class 2 or lower wind resource, which indicates that the resource in this area is marginally suitable for large-scale wind energy development or suitable for small-scale applications and could be useful as part of a hybrid energy system. It was further observed that wind turbines with a designed cut-in wind speed of less than 3 m/s and a moderate-rated wind speed of between 9 and 11 m/s are more suitable for wind energy development along Ghana's coast. Based on the selected wind turbines and the assumptions used in this study, it was estimated that the unit cost of electricity varied between GH¢0.0695 and GH¢0.2817/kW h.

14/02801 Development of a novel 2-stage entrained flow coal dry powder gasifier

Xu, S. *et al. Applied Energy*, 2014, 113, 318–323.

Coal-fired gasifiers are the key technology for clean power generation and coal chemical process. This paper presents a two-stage entrained flow dry powder gasifier in which coal is entrained into the lower chamber burner with oxygen and steam to raise the temperature of the crude gas up to 1700 °C. The lower chamber is linked to the upper gasification chamber through a middle throat, where additional coal and steam is fed to cool down the slag to less than 900 °C for deslagging from the lower chamber bottom. Various coals have been characterized and gasified with this two-stage entrained flow dry powder gasifier and comparisons made with single stage gasifiers. The results show that the two-stage gasifier is suitable for a broad range of coal varieties and gives carbon conversion up to 98.9% with cold syngas efficiency of 83.2% at a pressure of 3.0 MPa, while the oxygen and coal consumption are lower than with the single stage gasifier.

14/02802 Efficient fault-ride-through control strategy of DFIG-based wind turbines during the grid faults

Mohammadi, J. *et al. Energy Conversion and Management*, 2014, 78, 88–95.

As the penetration of wind power into the electrical power system increases, it is necessary that wind turbines remain connected to the grid and contribute to the system stability during and after grid faults. This paper proposes an efficient control strategy to improve the fault ride-through (FRT) capability of doubly fed induction generator (DFIG) during symmetrical and asymmetrical grid faults. The proposed scheme consists of active and passive FRT compensators. The active compensator is carried out by determining the rotor current references to reduce the rotor over-voltages. The passive compensator is based on rotor current limiter that considerably reduces the rotor inrush currents and clears the grid faults with deep sags. By applying the proposed strategy, negative effects of the grid faults in the DFIG system including the rotor over-currents, electromagnetic torque oscillations and DC-link over-voltage are decreased. The system simulation results confirm the effectiveness of the proposed control strategy.

14/02803 Energy management of flywheel-based energy storage device for wind power smoothing

Díaz-González, F. *et al. Applied Energy*, 2013, 110, 207–219.

Power fluctuations of wind generators may affect power quality especially in weak or isolated grids. This paper proposes an energy management strategy for a flywheel-based energy storage device. The aim of the flywheel is to smooth the net power flow injected to the grid by a variable speed wind turbine. The design of the energy management strategy is conducted through several phases. First, a definition and determination of the optimal operation of the storage device is carried out through the formulation and deterministic solution of an optimization problem using the General Algebraic Modeling System (GAMS). Based on this solution, an online energy management algorithm is proposed to achieve a close to optimal operation of the flywheel. This algorithm determines the set points of the torque control of the flywheel electrical machine. The proposed methodology is illustrated by simulations.

14/02804 Estimating the value of additional wind and transmission capacity in the rocky mountain west

Godby, R. *et al. Resource and Energy Economics*, 2014, 36, (1), 22–48.

The expansion of wind-generation in the USA poses significant challenges to policy-makers, particularly because wind's intermittency and unpredictability can exacerbate problems of congestion on a transmission-constrained grid. Understanding these issues is necessary if optimal development of wind energy and transmission is to occur. This paper applies a model that integrates the special concerns of electricity generation to empirically consider the challenges of developing wind resources in the Rocky Mountain region of the USA. Given the lack the high frequency data needed to address the special problems of intermittency and congestion, the solution here is to create a dispatch model of the region and to use simulations to generate the necessary data, then use this data to understand patterns that have occurred as wind resources have been developed. The results indicate that the price effects caused by changes in power output at intermittent sources are strongly dependent on supply conditions and the presence of market distortions caused by transmission constraints. Peculiarities inherent in electric grid operation can cause system responses that are not always intuitive. The distribution of the rents accruing to wind generation, particularly in unexpectedly windy periods are strongly dependent on the allocation of transmission rights when congestion occurs, which impacts potential returns to developing wind resources. Incidents of congestion depend on the pace of development of wind and transmission capacity. Not accounting for such distortions may cause new investment to worsen market outcomes if mistaken estimates of benefits or costs lead to sub-optimal development of wind and transmission facilities.

14/02805 Hydrodynamic performance of a vertical-axis tidal-current turbine with different preset angles of attack

Zhao, G. *et al. Journal of Hydrodynamics, Ser. B*, 2013, 25, (2), 280–287.

The instantaneous angle of attack on the blade has a significant effect on the hydrodynamic performance of a vertical-axis tidal-current turbine with straight blades. This paper investigates the influence of different preset angles of attack on the hydrodynamic performance of a three-bladed, vertical-axis, tidal-current turbine both experimentally and numerically. Experiments are carried out in a towing tank. This tested turbine's solidity is 0.1146. The preset angles of attack on the blade are $-3°$, $0°$, $3°$ and $5°$ in the experiments. Experimental results show that with the increase of the preset angle of attack from $-3°$ to $5°$, the hydrodynamic performance of the turbine is improved significantly with the power coefficients being increased from 15.3% to 34.8%, respectively. Compared to the result of a $0°$ preset angle of attack, the performance of the turbine with positive preset angles of attack is experimentally demonstrated to be beneficial. This performance improvement is also shown by numerical simulations based on the unsteady Reynolds averaged Navier–Stokes equations. In addition, the numerical results show that the optimal positive preset angle of attack is $7°$ for the turbine studied. The corresponding power coefficient is 38%. Beyond this optimal preset angle of attack, the hydrodynamic performance of the turbine decreases. Therefore, due to the dynamic stall phenomenon, an optimal preset angle of attack exists for any vertical-axis turbine. This value should be considered in the design of a vertical-axis tidal-current turbine.

14/02806 Modeling framework and validation of a smart grid and demand response system for wind power integration

Broeer, T. *et al. Applied Energy*, 2014, 113, 199–207.

Electricity generation from wind power and other renewable energy sources is increasing, and their variability introduces new challenges to the power system. The emergence of smart grid technologies in recent years has seen a paradigm shift in redefining the electrical system of the future, in which controlled response of the demand side is used to balance fluctuations and intermittencies from the generation side. This paper presents a modelling framework for an integrated electricity system where loads become an additional resource. Agent-based modelling is used to represent a smart grid power system integrating generators, transmission, distribution, loads and market. The model incorporates generator and load controllers, allowing suppliers and demanders to bid into a real-time pricing electricity market. The modelling framework is applied to represent a physical demonstration project conducted on the Olympic Peninsula, Washington, USA, and validation simulations are performed using actual dynamic data. Wind power is then introduced into the power generation mix illustrating the potential of demand response to mitigate the impact of wind power variability, primarily through thermostatically controlled loads. The results indicate that effective implementation of demand response to assist integration of variable renewable energy resources requires a diversity of loads to ensure functionality of the overall system.

14/02807 Performance prediction of a multi-MW wind turbine adopting an advanced hydrostatic transmission

Silva, P. *et al. Energy*, 2014, 64, 450–461.

This paper analyses the performance of multi-megawatt wind turbines by means of a specific numerical model, with the aim of evaluating the application of an advanced hydrostatic transmission in a conventional state-of-the-art machine. The interest for such a solution is mainly related to the potential increase of reliability and reduction of maintenance costs in spite of an expected reduction of performance. The implemented numerical algorithm considers the energy model of single components of the whole turbine drive-train, from the blades to the electric grid. The model is first applied to a conventional turbine and validated according to available yearly data from a wind farm. Then, it is used to calculate the annual energy production for different drive-train configurations applied to the same rotor, including the widespread solution with induction generator and inverter connected to the rotor, permanent magnet generator with direct drive connection or the proposed advanced hydrostatic transmission. The differences in yearly electricity output among the investigated configurations are within few percentage points.

14/02808 Performance prediction of active pitch-regulated wind turbine with short duration variations in source wind

Roy, S. *Applied Energy*, 2014, 114, 700–708.

Short-duration wind variations affect the real-time performance of active pitch-regulated wind turbines in two ways as evident from reported experimental and empirical studies. First, the mean output power, which may be referred to as the short duration output power, differs significantly from the corresponding zero-turbulence value obtained with ideal source wind streamlines. Second, random variation of output around the mean value appears with a significant standard deviation; the normalized value of which is referred to as the short duration variability. In this paper, analytical interpretation of both metrics is presented under assumption of two-parameter Weibull statistics for short duration wind variations. Statistical estimates for the metrics are presented for conditions described by the well-known IEC 61400–1 standards. Finally, the statistical estimation procedure is applied to a Vestas V90 3 MW zero-turbulence output curve as an illustrative application example.

14/02809 Procedural justice in wind facility siting: recommendations for state-led siting processes

Ottinger, G. *et al. Energy Policy*, 2014, 65, 662–669.

Evidence suggests that state control of wind facility siting decisions fosters new project development more effectively than local control, yet the literature suggests that affected citizens tend to be more fairly represented in local siting processes. The authors argue that successful renewable energy policy must satisfy both the need for new project development and the obligation to procedural justice. To suggest how it can do so, the authors analyse existing state- and county-level siting processes in Washington state, USA, finding that both fall short on measures of procedural justice. To overcome this limitation and address the tension between procedural justice and project development, a collaborative governance approach is then proposed to wind facility siting, in which state governments retain ultimate authority over permitting decisions but encourage and support local-level deliberations as the primary means of making those decisions. Such an approach, the authors argue, would be more just, facilitate wind development by addressing community concerns constructively and result in better projects through the input of diverse stakeholders.

14/02810 Quantifying CO_2 savings from wind power

Wheatley, J. *et al. Energy Policy*, 2013, 63, 89–96.

A method of quantifying operational CO_2 savings from wind power generation is described with reference to the 2011 Irish electricity grid. Based on an emissions model and $\frac{1}{2}$-hourly generation time-series for each grid connected thermal generator, it is estimated that wind power saved 0.28 tCO_2/MWh on average, relative to an implied average carbon intensity in the absence of wind of 0.52 tCO_2/MWh. These low savings are explained in terms of the response of individual thermal generators to intermittent wind generation.

14/02811 The incentive to invest in thermal plants in the presence of wind generation

Di Cosmo, V. and Valeri, L. M. *Energy Economics*, 2014, 43, 306–315.

In a deregulated market the decision to add generation rests with private investors. This paper evaluates how generator profits are affected by increasing wind generation. Using hourly historical data for Ireland's single electricity market, the authors simulate a new series of electricity prices, representative plant bids and wind generation. The model was calibrated based on the negative correlation between electricity prices and wind generation, which determined that increasing wind generation induces lower profits for all baseload plants.

Additionally, it decreases profits for baseload natural gas plants more than for the less flexible coal-fuelled plants, which might encourage investment in less flexible plants.

14/02812 The role of demand response in single and multi-objective wind-thermal generation scheduling: a stochastic programming

Falsafi, H. *et al. Energy*, 2014, 64, 853–867.

This paper focuses on using demand response (DR) as a means to provide reserve in order to cover uncertainty in wind power forecasting in smart grid (SG) environments. The proposed stochastic model schedules energy and reserves provided by both of generating units and responsive loads in power systems with a high penetration of wind power. This model is formulated as a two-stage stochastic programming, where the first stage is associated with the electricity market, its rules and constraints, and the second stage is related to the actual operation of the power system and its physical limitations in each scenario. The discrete retail customer responses to incentive-based DR programmes are aggregated by demand response providers (DRPs) and are submitted as a load change price and amount-offer package to the independent system operator. Also, price-based DR programme behaviour and the random nature of wind power are modelled by a price elasticity concept of the demand and normal probability distribution function, respectively. In the proposed model, DRPs can participate in the energy market as well as the reserve market and submit their offers to the wholesale electricity market. This approach is implemented on a modified IEEE 30-bus test system over a daily time horizon. The simulation results are analysed in six different case studies. The cost, emissions and multiobjective functions are optimized in both without and with DR cases. The multiobjective generation scheduling model is solved using the augmented epsilon constraint method and the best solution can be chosen by entropy and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods. The results indicate demand-side participation in energy and reserve scheduling reduces the total operation costs and emissions.

14/02813 Wind power evaluation and utilization over a reference high-rise building in urban area

Lu, L. and Sun, K. *Energy and Buildings*, 2014, 68, 339–350.

To help design wind turbines around numerous high-rise buildings with promising wind in Hong Kong, this paper presents an integrated method of both macro (weather data and domain topography) and micro aspect (computational fluid dynamics) analysis. Long-term wind data are compared at dense urban and small island stations. The prevailing wind is found to be from the east, and the average wind speed for the urban location is much lower, say 2.93 m/s at 25 m above ground level. The need to integrate wind turbines into high-rise buildings is necessary. This research demonstrates that the wind power density at 4 m above the building roof is enhanced numerously by 1.3–5.4 times with 5–7 m/s inlet velocity. Wind power utilization around the windward top roof is the most promising under the dominant wind direction. The thickness of wind speed below 8 m/s is only 3.6 m at these areas. Due to high-rise building height and concentration effects, the wind power enhancement for 7 m/s inlet velocity is around four times of that for 5 m/s, which is even larger than the cube of these two velocity ratio 7/5, i.e. 2.7 times determined from the general model between wind power and velocity.

Others, including economics

14/02814 A geographical information system (GIS) based methodology for determination of potential biomasses and sites for biogas plants in southern Finland

Höhn, J. *et al. Applied Energy*, 2014, 113, 1–10.

The objective of this study was to analyse the spatial distribution and amount of potential biomass feedstock for biomethane production and optimal locations, sizes and number of biogas plants in southern Finland in the area of three regional waste management companies. A geographical information system (GIS)-based methodology was used, which also included biomass transport optimization considering the existing road network and spatially varied biomass sources. Kernel density (KD) maps were calculated to pinpoint areas with high biomass concentration. The results show that the total amount of biomass corresponds to 2.8 TWh of energy of which agro materials account for more than 90%. It was found that a total of 49 biogas plants could be built in three case regions with feedstock available within maximum transportation radius of 10 or 40 km. With maximum of 10 km biomass transportation distance, the production capacity of the planned plants ranges from 2.1 to 8.4 MW. If transportation distance was increased to 40 km, the plant capacities could also increase from 2.3 to 16.8 MW. As shown in this study, the studied GIS methodology can be used for identification of the most suitable locations for biogas plants by providing the tools for transportation routes and distances, for example. The methodology can further be used in environmental impact assessment as well as in cost analysis.

14/02815 Assessing bioenergy potential in rural areas – a NEG-EROEI approach

Arodudu, O. *et al. Biomass and Bioenergy*, 2013, 58, 350–364.

Most sources of biomass are located in rural areas, and use of this biomass for bioenergy may be in conflict with agricultural and conservation purposes. This study applied life cycle inventory and geographical information system tools to estimate the net energy gain (NEG) and energy return on energy invested (EROEI) for different biomass/bioenergy production activities in rural areas. The focus was on those activities that are least damaging or even socially, environmentally or economically beneficial. The authors considered bioenergy production from crop residues, manure, and grass in natural grasslands and surplus pasturelands. The feasibility and vulnerability of different sources was assessed within the context of existing policy constraints, and the potential contribution to the European Union's bioenergy targets was evaluated. Taking the Overijssel province in the Netherlands as a case study, the authors showed that 66.01 PJ can be contributed from by-products, with an additional 3.34 TJ coming from more conventional pasturelands. The NEG from biogas can potentially take care of Overijssel's entire renewable energy target for the year 2030. When producing bioenergy from by-products, the EROEI is quite high (7–17), indicating that there is a big potential for by-products to provide energy without compromising the ecological or agricultural functions of the landscapes. However there are still many changes in the practices, technologies and policies associated with bioenergy production that have to be made to harvest this potential energy resource.

14/02816 Assessment of the impacts of tidal stream energy through high-resolution numerical modeling

Ramos, V. *et al. Energy*, 2013, 61, 541–554.

When planning the installation of a tidal farm, the disturbances on the marine environment associated with its operation must be studied in detail. The objectives of this paper are to assess the impacts on the hydrodynamics (water level and flow velocity) and to determine how these impacts can alter the tidal resource. For this purpose, a high-resolution model of Ria de Ribadeo (north-west Spain) is used to describe the potential effects resulting from the operation of two prospective tidal farms. Two different scenarios of extracted power from the flow (high and low) are analysed. Overall, it is found that the impact on the water level is negligible, but that on the flow velocity is significant. The velocity is reduced upstream and downstream from the farm, and increased beside it. These effects are enhanced in the scenario with the higher power extraction. Finally, these modifications in the flow pattern alter the available energy density at the tidal turbine, with a reduction of 21% and 12% for the high and low levels of power extraction, respectively.

14/02817 Bioenergetic potential of agricultural soils in Slovakia

Vilček, J. *Biomass and Bioenergy*, 2013, 56, 53–61.

Knowledge of the energy potential of an agricultural soil and the potential production of biomass, together with economic parameters, can help pinpoint more effective sites for growing plants for traditional purposes and for fuel production. There is approximately 10,206 PJ of potential energy accumulated in Slovakia's agricultural soils. The lowest utilization was found in the Cambisols soil type (0.7–1.8%) and the highest in Regosols (3.1–7.0%). The bioenergy production potential of agricultural soils in Slovakia was determined for chosen soil parameters according to the production of the plants grown. With regard to energy, the most productive are soils of the Chernozem type ($25.1\,\mathrm{MJ\,m^{-2}}$) and Mollic Fluvisols ($22.5\,\mathrm{MJ\,m^{-2}}$). Gleysols, Histosols, Solonetz and Leptosols (3.0–$5.0\,\mathrm{MJ\,m^{-2}}$) produce the lowest bioenergy levels. The highest energy production precondition ($22.2\,\mathrm{MJ\,m^{-2}}$) occurs in soils in the very warm, very dry lowland climatic region. According to the granularity, the most energy (14.0–$15.0\,\mathrm{MJ\,m^{-2}}$) is produced by deep clayey soils ($18.0\,\mathrm{MJ\,m^{-2}}$) in a slope to 3° ($18.3\,\mathrm{MJ\,m^{-2}}$) that are not or sporadically gravelly ($19.2\,\mathrm{MJ\,m^{-2}}$). The highest energy yields can be expected from the biomass of plants grown in arable land (approximately $11.0\,\mathrm{MJ\,m^{-2}}$). Regarding the efficiency of economic and financial inputs, plants growing in Chernozem, Mollic Fluvisols, Fluvisols and Haplic Luvisols soil types in very warm, very dry, lowlands to warm, very dry, basin-like, continental climatic regions appear to be profitable in slopes to 7°, with no or only a sporadic gravel content.

14/02818 Carbon and environmental footprinting of global biofuel production

Hammond, G. P. and Seth, S. M. *Applied Energy*, 2013, 112, 547–559.

The carbon and environmental footprints associated with the global production of biofuels have been computed from a baseline of 2007–2009 out until 2019. Estimates of future global biofuel production were adopted from OECD–FAO and related projections. In order to determine the footprints associated with these (essentially ‘first generation’) biofuel resources, the overall environmental footprint was disaggregated into bioproductive land, built land, carbon, embodied energy, materials and waste, transport, and water components. The global carbon footprint of biofuels was estimated to be 0.248 billion (bn) global hectares (gha) in 2010; arising to 0.449 bn gha by 2019. The total environmental footprint for the global production of biofuels was estimated to be 0.720 bn gha for 2010; rising to 1.242 bn gha by 2019. Bioproductive land use proved to give rise to the highest element of the footprint, with the ‘carbon footprint’ as the next highest, followed by the water footprint, and then the transport component. The waste, built land and embodied energy components contributed an insignificant amount to the total environmental footprint.

14/02819 Considering linear generator copper losses on model predictive control for a point absorber wave energy converter

Andrade, D.-E. M. *et al. Energy Conversion and Management*, 2014, 78, 173–183.

The amount of energy that a wave energy converter can extract depends strongly on the control strategy applied to the power take-off system. It is well known that, ideally, the reactive control allows for maximum energy extraction from waves. However, the reactive control is intrinsically non-causal in practice and requires some kind of causal approach to be applied. Moreover, this strategy does not consider physical constraints and this could be a problem because the system could achieve unacceptable dynamic values. These, and other control techniques, have focused on the wave energy extraction problem in order to maximize the energy absorbed by the power take-off device without considering the possible losses in intermediate devices. In this sense, a reactive control that considers the linear generator copper losses has been recently proposed to increase the useful power injected into the grid. Among the control techniques that have emerged recently, the model predictive control represents a promising strategy. This approach performs an optimization process on a time prediction horizon incorporating dynamic constraints associated with the physical features of the power take-off system. This paper proposes a model predictive control technique that considers the copper losses in the control optimization process of point absorbers with direct drive linear generators. This proposal makes the most of reactive control as it considers the copper losses, and it makes the most of the model predictive control, as it considers the system constraints. This means that the useful power transferred from the linear generator to the power converters increases. In this sense, the average power delivered to the grid increases and the implementation viability improves. In this paper, the results of the simulations are compared with those obtained from other control strategies in irregular waves.

14/02820 Design of a horizontal axis tidal current turbine

Goundar, J. N. and Ahmed, M. R. *Applied Energy*, 2013, 111, 161–174.

Pacific Island countries (PICs) have a huge renewable energy potential to meet their energy needs. Limited resources are available on land; however, large amount of ocean energy is available and can be exploited for power generation. PICs have more sea-area than land-area. Tidal current energy is very predictable and large amount of tidal current energy can be extracted using tidal current energy converters. A 10 m diameter, three-bladed horizontal axis tidal current turbine (HATCT) is designed in this work. Hydrofoils were designed for different blade locations; they are named as HF10XX. The hydrodynamic characteristics of the hydrofoils were analysed. A thick hydrofoil with a maximum thickness of 24% and a maximum camber of 10% was designed for the root region. The maximum thickness of hydrofoils was varied linearly from the root to the tip for easier surface merging. For the tip region, a thinner hydrofoil of maximum thickness 16% and maximum chamber 10% was designed. It was ensured that the designed hydrofoils do not experience cavitation during the expected operating conditions. The characteristics of the HF10XX hydrofoils were compared with other commonly used hydrofoils. The blade chord and twist distributions were optimized using blade element momentum theory. The theoretical power output and the efficiency of the rotor were also obtained. The maximum power at the rated current of 2 m/s is 150 kW and the maximum efficiency is 47.5%. The designed rotor is found to have good efficiency at current speeds of 1–3 m/s. This rotor has better performance than some other rotors designed for HATCT.

14/02821 Design of a renewable energy based air-conditioning system

Prasartkaew, B. and Kumar, S. *Energy and Buildings*, 2014, 68, 156–164.

This paper presents the design of a solar–biomass hybrid system for air-conditioning. Three possible overall system configurations were considered, based on which the most suitable configuration considered for the design. The principles of component selection of a flat plate solar collector with storage, biomass gasifier with boiler, and a LiBr–H_2O absorption system has been described, and the design criteria for the proposed system elaborated. The design was to satisfy a cooling load of 4.5 kW, and solar to auxiliary heat ratio of at least 0.7. Simulation at various solar collector size and storage tank volume for the weather conditions in Bangkok, Thailand, indicate the most suitable design and specifications for the size/capacity of the solar collector, storage tank, set point temperature of the absorption generator and biomass-gasifier boiler.

14/02822 Economic analysis of hybrid system consists of fuel cell and wind based CHP system for supplying grid-parallel residential load

Ranjbar, M. R. *et al. Energy and Buildings*, 2014, 68, 476–487.

An evolutionary programming-based approach to evaluate the effect of combining fuel cell power plants (FCPP) and wind on the operational and performance cost is presented in this paper. The fluctuating nature of wind energy (WE) has different effects on the system constraints and operational cost. Moreover, FCPPs are able to produce both thermal and electrical energy simultaneously. Results manifest that through combining FCPP and WE in a hybrid structure for combined heat and power systems, causes lower operational cost than that of individual units. In order to consider production cost of energy, electrical power from WE, power trade with the local grid, thermal recovery from the FCPP, start-up cost of FCPP and maintenance cost; an integrated cost model for FCPP and WE is constructed. A 6-min thermal and electrical load profiles for a residential house in Mashhad Province, Iran is engaged along with the wind speed variation to specify the best cost-effective strategy. According to electrical and thermal load demand, available wind power and different tariffs for purchasing and selling electricity of local grid the operation of the FCPP system is scheduled to optimize operational cost. Encouraging results indicate feasibility of the proposed technique.

14/02823 Emergence of green business models: the case of algae biofuel for aviation

Nair, S. and Paulose, H. *Energy Policy*, 2014, 65, 175–184.

Emergent business models seek to take advantage of new market mechanisms driven by technological changes, particularly those related to the production and delivery of clean or sustainable energy. Such business models often function at the intersection of various industries, with global views, and the resulting systems have distinct social, political, environmental, economic, technological and business dimensions. Such holistic systems are not only difficult to develop but also require support from a broad range of actors with effective regulations and policies in place, such that the firm functions within a framework that integrates various factors. This study substantiates such a framework by detailing the nascent algae-based biofuel industry that caters to the aviation sector while arguing that businesses in the energy industry can emerge as a next-practice platform that drive a sixth wave of innovation. The framework begins with three basic enablers, innovation, flexibility and sustainability, and explains how value from renewable energy technologies can be created and captured sustainably and innovatively with new market mechanisms implemented by firms with green business models.

14/02824 Evaluation of the environmental sustainability of a micro CHP system fueled by low-temperature geothermal and solar energy

Ruzzenenti, F. *et al. Energy Conversion and Management*, 2014, 78, 611–616.

This paper evaluates the environmental sustainability of a small combined heat and power (CHP) plant operating through an organic Rankine cycle (ORC). The heat sources of the system are from geothermal energy at low temperature (90–95 °C) and solar energy. The designed system uses a solar field composed only of evacuated, non-concentrating solar collectors, and work is produced by a single turbine of 50 kW. The project addresses an area of Tuscany in Italy, but it could be reproduced in areas where geothermal energy is extensively developed. Therefore, the aim is to exploit existing wells that are either unfit for high-enthalpy technology, abandoned or never fully developed. Furthermore, this project aims to aid in downsizing the geothermal technology in order to reduce the environmental impact and better tailor the production system to the local demand of combined electric and thermal energy. The environmental impact assessment was performed through a life cycle analysis and an exergy life cycle analysis. According to the findings, the reservoir is suitable for a long-term exploitation of the designed system, however, the sustainability and the energy return of this latter is edged by the surface of the heat exchanger and the limited running hours due to the solar plant. Therefore, in order to be comparable to other renewable resources or geothermal systems, the system needs to develop existing wells, previously abandoned.

14/02825 EXPANSE methodology for evaluating the economic potential of renewable energy from an energy mix perspective

Trutnevyte, E. *Applied Energy*, 2013, 111, 593–601.

Several methodologies exist for evaluating the economic potential of renewable energy sources. These methodologies either cannot capture how this economic potential depends on its embedding in the whole energy mix, or provide a single cost-optimal energy mix, which is not flexible enough for building consensus among the relevant stakeholders. This paper addresses these two limitations and introduces a novel methodology EXPANSE (EXploration of PAtterns in Near-optimal energy ScEnarios) for evaluating the economic potential of renewable energy sources from an energy mix perspective. This methodology is based on generation of cost-optimal and multiple near-optimal energy mixes. These mixes show the maximum, technically feasible, cost-effective potential of a renewable energy source under consideration and how this potential depends on the other supply alternatives and energy savings in an energy mix. The methodology is illustrated with the example of the renewable energy use for heat supply in a Swiss region. The example shows that even a particular renewable energy source is costlier than the currently deployed alternatives such as oil, its economic potential in an energy mix can be as high as its full exploitable (theoretical) potential, when some deviation is allowed from the cost-optimal energy mix. However, the full economic potential of all renewable energy sources cannot be utilized simultaneously. The full deployment of the economic potential of one renewable energy source decreases the economic potential of others. EXPANSE provides basis for analysing such interlinkages.

14/02826 Experimental evaluation of using various renewable energy sources for heating a greenhouse

Esen, M. and Yuksel, T. *Energy and Buildings*, 2013, 65, 340–351.

The interest in alternative or renewable energy sources for greenhouse heating is currently high, owing to the large heating loads and the relatively high price of fossil fuels. Important alternative sources of energy are solar collectors, heat pumps, biomass and cogeneration systems. This study experimentally investigates greenhouse heating by biogas, solar and ground energy in Elazig, Turkey. The greenhouse (6 m × 4 m × 2.10 m) heated by mentioned alternative energy sources was constructed, and the required heating load of the greenhouse was determined. For this purpose, a biogas, solar and a ground source heat pump greenhouse heating system with a horizontal slinky ground heat exchanger was designed and set up. Experiments were conducted extensively during the winter period from November 2009 to March 2010. During the experiments, 2231.83 litres of gas production by biogas system was provided. The experiments that are required for the growth of many plants need temperature of 23 °C, and conceivable success has been achieved in reaching this value by built systems. As a result, different energy sources have been successfully tested for greenhouse heating.

14/02827 Missed opportunities and lessons learned, evaluation of the initiative on B30 biodiesel in the CIVITAS project of the Belgian city Ghent

Anthonis, T. *et al. Biomass and Bioenergy*, 2013, 57, 191–195.

In the framework of the European CIVITAS project in Ghent, Belgium, the initiative was taken to introduce B30 biodiesel in the city car fleet. Yet, implementation turned out to be difficult due to a combination of reasons which will be discussed in detail in this paper. First of all, there is no consistent policy on the taxation of high-blend biofuels in Belgium. Furthermore, questions and misconceptions on technical aspects lead to distrust by the consumers and retailers, often resulting in the needless withdrawal of the vehicle warranty. Finally, the lack of a good monitoring programme to measure emissions, impact on car maintenance and B30 economics during the project is seen as a missed opportunity.

14/02828 Performance analysis of a rooftop wind solar hybrid heat pump system for buildings

Li, Q.-Y. *et al. Energy and Buildings*, 2013, 65, 75–83.

Using wind and solar energies coupled with heat pumps is a promising technology for energy conservation and emissions reduction. This paper describes a rooftop wind solar hybrid heat pump system for supplying a building's hot water, heating and cooling loads and presents energy and exergy analyses as well as an environmental benefits assessment. The system consists of a shrouded wind-lens turbine subsystem, a flat-plate solar thermal subsystem and a water/air source heat pump subsystem, where the wind and solar subsystems are compactly installed on the rooftop. The solar collector heats water for supplying domestic hot water and increasing the heat pump evaporation temperature for room heating. Heat pumps are used for room heating and cooling and auxiliary heating domestic hot water. Wind power contributes to satisfying the heat pump power demand. Energy and exergy analyses show that the solar thermal subsystem is exergetically inefficient and thus a better design of the solar collector can improve the system exergy efficiency. Wind power can provide 7.6% of the yearly heat pump power demand to satisfy the thermal loads of a 198 m^2 residential building in Beijing. The system can yearly reduce 31.3% carbon dioxide emission compared with conventional energy systems.

14/02829 Performance comparison of renewable incentive schemes using optimal control

Oak, N. *et al. Energy*, 2014, 64, 44–57.

Many governments worldwide have instituted incentive schemes for renewable electricity producers in order to meet carbon emissions targets. These schemes aim to boost investment and hence growth in renewable energy industries. This paper examines four such schemes: premium feed-in tariffs, fixed feed-in tariffs, feed-in tariffs with contract for difference and the renewable obligations scheme. A generalised mathematical model of industry growth is presented and fitted with data from the UK onshore wind industry. The model responds to subsidy from each of the four incentive schemes. A utility or 'fitness' function that maximizes installed capacity at some fixed time in the future while minimizing total cost of subsidy is postulated. Using this function, the optimal strategy for provision and timing of subsidy for each scheme is calculated. Finally, a comparison of the performance of each scheme, given that they use their optimal control strategy, is presented. This model indicates that the premium feed-in tariff and renewable obligation scheme produce the joint best results.

14/02830 Possible impact of the Renewable Energy Directive on N fertilization intensity and yield of winter oilseed rape in different cropping systems

Pahlmann, I. *et al. Biomass and Bioenergy*, 2013, 57, 168–179.

In 2009, the European Union's Renewable Energy Directive (RED), established sustainability criteria for biofuels including legal thresholds for specific greenhouse gas (GHG) emissions, expressed as grams of CO_2eq per MJ of biofuel. Because biofuels are a major market for winter oilseed rape (WOSR), investigating the possible impact of the RED on WOSR cropping practices is prudent. This study analyses GHG emissions for WOSR cropping practices (namely N fertilization intensity, tillage method and crop rotation) basing on a 6-year field trial in a high yielding area of northern Germany. Using the International Panel on Climate Change methodology the field emissions of nitrous oxide (N_2O) are calculated from the nitrogen (N) inputs to the cropping system. Results showed that the predominant source of GHG emissions is the N related emissions from production of fertilizer and N_2O field emissions. Specific GHG emissions are lowest without N fertilizer but rise continuously with increasing N rates. Yield per hectare also responded to N fertilization resulting in lowered acreage productivity when reducing GHG emissions by reducing N fertilization level. Most calculated scenarios and cropping systems result in a drastic decrease of N fertilization to achieve thresholds, causing substantial yield losses. To a certain extent, the required drastic reduction of N fertilization in some scenarios is driven by using the IPCC methodology for calculating N_2O emissions. Therefore characteristics of this methodology are also discussed within this study. To mitigate the impact of the RED on WOSR, peas (legumes) may be a possible preceding crop to WOSR.

14/02831 Price relationships and market integration in the Swedish wood fuel market

Olsson, O. and Hillring, B. *Biomass and Bioenergy*, 2013, 57, 78–85.

Cointegration analysis is applied to the prices of three different wood fuel assortments in the Swedish market: refined wood fuels, forest chips and industrial by-products. For the latter two, the price series are separated according to two consumer categories: district heating (DH) plants and industrial consumers. Two types of analyses are performed. The first concerns whether the fuels within each consumer group can be bundled together as belonging to the same market in terms of product homogeneity. The second involves analysis of the prices of homogeneous fuels in the two consumer categories. It is found that in the DH sector, refined wood fuels should be observed as a separate market because their prices do not share a common trend with the prices of any of the other fuels. This lack of a common trend is likely due to the highly internationalized nature of the wood pellet market. The DH prices of forest chips and industrial by-products follow a common trend, as do the prices paid for industrial by-products by DH plants and industrial consumers. The prices of forest chips paid by industrial consumers and DH plants do not share a common trend. The prices paid by industrial consumers for industrial by-products and forest chips also do not share a common trend. These results highlight both the differences between the markets for unrefined and refined wood fuels and the presence of inefficiencies in the Swedish wood fuel market.

14/02832 Production and use of electrolytic hydrogen in Ecuador towards a low carbon economy

Pelaez-Samaniego, M. R. *et al. Energy*, 2014, 64, 626–631.

This paper presents a pre-feasibility study for producing and using electrolytic hydrogen in Ecuador as part of a strategy towards a low carbon economy. Hydrogen could be produced using hydropower either alone or combined with other renewable energy sources. This study analysed two scenarios of energy availability based on data from the largest hydroelectric power plant in the country. The first scenario assumes that an amount of water equivalent to 30% of that spilled in 2011 could be used to generate additional electricity. Thus, an additional amount of energy equivalent to 5% of the energy produced in 2011 could be available. The second scenario doubles this amount of energy. Economic analysis showed that to obtain low-cost hydrogen (US$3.00/kg) it is necessary to operate the electrolysis plants 24 h/day, using low-cost electricity ($30/MWh). A continuous supply of energy could be possible when new hydroelectric utilities start operating or by integrating hydropower with solar and wind. Three possibilities for using hydrogen are discussed: (1) production of ammonia as a raw material for nitrogenous fertilizers, (2) hydro-treating heavy oils and bio-oils in oil refineries and (3) as an energy storage medium to offset natural instability and unpredictability of renewables.

14/02833 Public acceptance of marine renewable energy in Malaysia

Lim, X.-L. and Lam, W.-H. *Energy Policy*, 2014, 65, 16–26.

Research and development on marine renewable energy (MRE) in Malaysia is still in its initial stage. It is crucial to know the level of acceptance of MRE among Malaysians in order to push the technology forward. A survey was conducted to investigate public acceptance of MRE in SS2, Petaling Jaya. In addition, a face-to-face interview was conducted to understand the concerns of an investor about investing in renewable energy (RE) projects. The results of analysis showed that 82.8% of the respondents support MRE implementation in Malaysia. However, 56.8% of the respondents are reluctant to pay for green electricity. The reason is directly linked to the ‘not in my backyard’ attitudes of some Malaysian citizens. They are unwilling to support green energy by involving themselves, participating or paying money. Furthermore, the interviewee, on behalf of investors, expressed some opinions on concerns about investment in RE projects that several ministries and departments are suggested as being important in MRE development.

14/02834 Risk management of hydropower development in China

Tang, W. *et al. Energy*, 2013, 60, 316–324.

There is a rapidly increasing demand for hydropower in China. However, little research has been conducted to systematically investigate the overall aspects of hydropower development risks. With support of the data collected from a fieldwork survey, this study reports the multiple facets of hydropower development risks in China as perceived by main project participants. All groups have a common view on the criticality of safety, and the groups also have their own priorities, i.e. resettlement of migrants, incompetence of subcontractors, project delay, inadequate or incorrect design, premature failure of facilities and ecological and environmental impacts are the key risks to clients, whereas quality of work, financial related risks, reputation, and claims and disputes are the main concerns to contractors. A case study of Three Gorges Project further demonstrates that, hydropower development risks can be effectively managed by encouraging joint efforts of all participants to achieve the goals on producing renewable energy, reducing emissions of CO_2, and providing important social/economic benefits. Future hydropower development should emphasize the interactions between project delivery, environmental, and economical processes to reach appropriate trade-offs among involving stakeholders, by adequately considering the inter-relations between project participants’ risks as well as hydropower project’s externalities on a broad view.

14/02835 Short-term hydro generation scheduling of Three Gorges–Gezhouba cascaded hydropower plants using hybrid MACS-ADE approach

Mo, L. *et al. Energy Conversion and Management*, 2013, 76, 260–273.

Short-term hydro generation scheduling (STHGS) aims to determine optimal hydro generation scheduling to obtain minimum water consumption for one day or week while meeting various system constraints. In this paper, the STHGS problem is decomposed into two sub-problems: (i) the unit commitment (UC) sub-problem, and (ii) the economic load dispatch (ELD) sub-problem. The authors present a hybrid algorithm based on multi-ant colony system (MACS) and differential evolution (DE) for solving the STHGS problem. First, MACS is used for dealing with UC sub-problem. A set of ant colonies co-operate to choose the unit state over the scheduled time horizon. Then, the adaptive differential evolution (ADE) is used to solve ELD sub-problem. MACS and ADE are run in parallel with adjusting their solutions in search of a better solution. Meanwhile, local and global pheromone updating rules in MACS and adaptive dynamic parameter adjusting strategy in DE are applied to enhance the search ability of MACS-ADE. Finally, the proposed method is implemented to solve STHGS problem of Three Gorges–Gezhouba cascaded hydropower plants to verify the feasibility and effectiveness. Compared with other established methods, the simulation results reveal that the proposed MACS-ADE approach has the best convergence property, computational efficiency with less water consumption.

14/02836 Techno-economical analysis of stand-alone hybrid renewable power system for Ras Musherib in United Arab Emirates

Rohani, G. and Nour, M. *Energy*, 2014, 64, 828–841.

The aim of this study is to model and design a hybrid renewable energy system for the remote area in Ras Musherib located in the western region of Abu Dhabi. The hybrid system, which consists of photovoltaic (PV) array, wind turbines, batteries and diesel generators, is designed to meet three known electric loads, 500 kW, 1 MW and 5 MW to be able to fulfil the primary load for 250, 500 and 2500 households. Different combination of wind turbines, PV, batteries and generators were evaluated in order to determine the optimal combination of the hybrid system based on the lower net present cost method. The proposed hybrid system is modelled, optimized and simulated using Hybrid Optimization Model for Electric Renewable (HOMER). The obtained results show that the hybrid system with 15% of PV and 30% of wind turbine penetration found to be the optimal system for 500 kW average load with initial cost of $4,040,000 and total net present cost of $14,504,952 over 25 years. The reduction in CO_2 emissions achieved in this study for the 500 kW optimal hybrid system was 37% compared to the conventional diesel generator-only power system.

14/02837 The exploitation of biomass for building space heating in Greece: energy, environmental and economic considerations

Michopoulos, A. *et al. Energy Conversion and Management*, 2014, 78, 276–285.

The exploitation of forest and agricultural biomass residues for energy production may offer significant advantages to the energy policy of the relevant country, but it strongly depends on a number of financial, technological and political factors. The work in hand focuses on the investigation of the energy, environmental and financial benefits resulting from the exploitation of forest and agricultural biomass residues, fully substituting the conventional fuel (diesel oil) for building space heating in Greece. For this investigation, the energy needs of a representative building are determined using EnergyPlus software, assuming that the building is located across the various climate zones of Greece. Based on the resulting thermal energy needs, the primary energy consumption and the corresponding emissions are determined, while an elementary fiscal analysis is also performed. The results show that significant financial benefits for the end-user are associated with the substitution examined, even though increased emissions and primary energy consumption have been derived.

14/02838 The hydrologic and economic feasibility of micro hydropower upfitting and integration of existing low-head dams in the United States

Sandt, C. J. and Doyle, M. W. *Energy Policy*, 2013, 63, 261–271.

The integration of hydropower facilities on existing low-head, non-Federal dams and their subsequent tie to regional electricity grids may serve as a useful decentralized component of renewable energy integration in the USA. Thousands of low-head dams do not provide power and thus present few benefits with significant costs, including safety liability, fragmentation of river ecosystems and persistent economic burden induced on state agencies due to regular inspection requirements. The authors conducted a feasibility study in the Piedmont region of North Carolina cataloguing over 1000 non-Federal dams with hydraulic heads ranging from 4.6 to 10.7 m (15–35 ft) and power capacity <300 kW (‘micro’ hydropower). Generation potential, greenhouse gas reductions and financial viability were refined for 49 low-head dams over a 30-year life cycle using industry standard software (RETScreen4). Results suggest that most of these dams are not financially viable for energy production under cost structures evaluated at the time of this study. However, the results indicate that some low-head dams may be viable for energy production if provided with funding opportunities comparable to the concurrent wind and solar markets.

14/02839 Vulnerability of hydropower generation to climate change in China: results based on grey forecasting model

Wang, B. *et al. Energy Policy*, 2014, 65, 701–707.

This paper analyses the long-term relationships between hydropower generation and climate factors (precipitation), hydropower generation capacity (installed capacity of hydropower station) to quantify the vulnerability of renewable energy production in China for the case of hydropower generation. Furthermore, this study applies a grey forecasting model to forecast precipitation in different provinces, and then sets up different scenarios for precipitation based on the IPCC Special Report on Emission Scenarios and results from PRECIS (Providing Regional Climate projections for Impacts Studies) model. The most important result found in this research is the increasing hydropower vulnerability of the poorest regions and the main hydropower generation provinces of China to climate change. Other main empirical results reveal that the impacts of climate change on the supply of hydropower generation in China will be noteworthy for the society. Different scenarios have different effects on hydropower generation, of which A2 scenario (pessimistic, high emission) has the largest. Meanwhile, the impacts of climate change on hydropower generation of every province are distinctly different, of which the Southwest part has the higher vulnerability than the average level while the central part lower.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

14/02840 3D laser imaging for surface roughness analysis

Mah, J. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 58, 111–117.

Three-dimensional (3D) images of rock faces contain key information for rock mass characterization. In an underground field trial, 3D laser imaging is used to measure surface roughness. A controlled validation study is performed comparing surface roughness measured manually and from the 3D data. At the same location as the manual measurements, joint orientation is first measured from the 3D point cloud data using principal component analysis. This process calculates the best fitting plane and its associated normal vector to the imaged joint surface. The normal vector being known, a 2D surface profile can be generated along the strike and dip. The profile length of the maximum asperity amplitude measured from the 3D data is used to estimate the joint roughness coefficient. In addition, the 3D point cloud data contains a wealth of information typically not available. The surface roughness measurements can be made across the entire image to generate a surface roughness map. Joint characteristics such as surface roughness anisotropy can be evaluated efficiently.

14/02841 An experimental study on runup of two solitary waves on plane beaches

Xuan, R.-t. *et al. Journal of Hydrodynamics, Ser. B*, 2013, 25, (2), 317–320.

Experiments of the run-up of two solitary waves on a plane beach are carried out in a wave flume. The two solitary waves with the same amplitude and the crest separating distances are generated by using an improved wave generation method. It is found that, with regard to the two solitary waves with same wave amplitude, the run-up amplification of the second wave is less than that of the first wave if the relative crest separating distance is reduced to a certain threshold value. The run-down of the first solitary wave depresses the maximum run-up of the second wave. If the leading solitary wave is of relatively smaller amplitude for the two solitary waves, the run-up amplification is affected by the overtaking process of two solitary waves. It turns out that the run-up amplification of the second wave is larger than that of the first wave if the similarity factor is approximately larger than 15, which means the larger wave overtakes the smaller one before the waves run-up on a beach.

14/02842 Design and performance of a new device for the study of thermophoresis: the radial flow thermophoretic analyser

Brugière, E. *et al. Journal of Aerosol Science*, 2013, 61, 1–12.

A new device to study the thermophoresis of particles is presented in this paper. The instrument, called a radial flow thermophoretic analyser, is based on the geometry of the radial flow differential mobility analyser or SMEC (*spectromètre de mobilité electrique circulaire*). The device uses two circular plates, each with hot and cold temperature imposed. The instrument was designed with computational fluid dynamic software in order to check uniformity of the temperature field in the selection area after an establishment length. The transfer function of the instrument is then established and determines the effective thermophoretic velocity of particles selected in the temperature field imposed in the apparatus. For the experimental validation, effective thermophoretic velocities of monodispersed spherical latex particles for diameters ranging from 64 to 500 nm and a temperature gradient equal to 50,750 K/m are measured and compared with theoretical values. The results show good repeatability and discrepancies with theoretical values less than 7%.

14/02843 Design of forest energy supply networks using multi-objective optimization

Kanzian, C. *et al. Biomass and Bioenergy*, 2013, 58, 294–302.

The replacement of fossil fuels with forest biomass should help mitigate greenhouse gas (GHG) emissions. However the supply of energy wood is challenging because of high supply costs and rapidly increasing demand. Given, the heterogeneous structure of landownership, contractors and energy producers in mid-Europe, supply network optimization is of major importance. A multi-criteria optimization problem (MOP) has been formulated, whereby the profit must be maximized and the CO_2 emissions have to be minimized. The objective function includes decisions about chipping location, transport mode and volume and terminals used. To solve the MOP, the weighted sum scalarization approach was used to derive Pareto optimal points by stepwise changing weights from maximum profit to minimal CO_2 emissions. The MOP was applied to a large-scale network of approximately 10,000 sources, 356 storage locations, 119 freight stations and 228 sinks with a demand of 982,000 $t\,a^{-1}$. In an effort to minimize CO_2 emissions, 30% of the woody biomass should be delivered chipped from the terminals and more than 50% chipped directly from forest. This results in CO_2 emissions of 24.3 $kg\,t^{-1}$ and a profit of 3.0 $€\,t^{-1}$. The rest has to be transported in solid form directly from forest to plant. By changing the weight to maximize the profit, CO_2 emissions will only increase by 4.5%, whereas the profit more than doubles from 3.0 to 7.4 $€\,t^{-1}$. The average transport distance increases from 45.7 to 48.1 km and 73% of all terminals are used.

14/02844 Determination of the sun area in sky camera images using radiometric data

Alonso, J. *et al. Energy Conversion and Management*, 2014, 78, 24–31.

The increasing development and expansion of solar power plants means that it is necessary to understand all the factors and occurrences that can affect the dynamics and quality of their output. The importance of clouds in the attenuation of solar radiation is a transcendental and decisive factor in the incident energy from the sun. Detecting clouds with sky cameras is a very problematic issue. The captured solar area in the images exhibits a pronounced saturation of pixels as a consequence of sunlight penetration and the appearance of various atmospheric features. The present paper describes a methodology based on radiometric data that is used to determine the causes of saturation in the solar zone and its vicinity on images from a TSI-880 model sky camera. The correct method identifies the presence or absence of clouds in the saturated zone with 92% success.

14/02845 Development of a suitable synthetic projection to simultaneously study solar exposure and natural lighting in building windows

Ramírez, E. *et al. Energy and Buildings*, 2013, 65, 391–397.

The level of comfort inside buildings is highly related to daylight availability, which is associated with solar access, irradiation on windows as well as solar rights. These mentioned variables are frequently calculated using similar methods. For the graphic study of these variables, mathematical projections are used which provide a geometric view of the analytical results. However, the existing projections are not suitable for calculating and representing sky vault luminance. This paper presents a synthetic projection developed specifically for vertical windows in order to study and determine the main variables associated with solar exposure and natural lighting according to the International Commission on Illumination standard overcast sky model recognized in the ISO standard. The proposed projection of the sky vault visible from a window provides insight on the problems related to natural lighting, shading and solar access, while aiding in solar access decision making.

14/02846 Dynamical behaviors of self-interstitial atoms in tungsten

Zhou, W. H. *et al. Journal of Nuclear Materials*, 2013, 437, (1–3), 438–444.

The motion mechanisms and jump rate of single self-interstitial atoms (SIAs) are studied by molecular dynamics simulations and vibration analysis. The migration of SIAs is a sequent transformation between the $\langle 111 \rangle$ crowdion and dumbbell with a 0.027 eV energy barrier. A soft mode contributes to this transformation, whose eigenvector shows that the atoms compressed by the SIAs have the largest amplitude. The jump rate of SIAs migration reaches 1 Hz at 12 K, which suggests that the thermal migration of SIAs dominates the nucleation of SIAs loops below 50 K. SIAs rotate between the [1 1 1] and its equivalent directions with a 0.668 eV energy barrier, which is controlled by a linear combination of libration and stretching mode. The results show that the long wave phonon induced by the stress field of SIAs plays an important role in the one-dimensional motion of SIAs.

14/02847 Effect of bidirectional mass transfer on non-isothermal gas absorption process

Kim, D. S. *International Journal of Thermal Sciences*, 2013, 67, 167–176.

The simultaneous heat and mass process in a binary gas–liquid mixture is modelled by reformulating the classical two-film theory. The original expression from the two-film model is reformulated to obtain algebraic equations where all interfacial quantities are explicitly described in terms of bulk conditions. Use of the new formulation is demonstrated in the analysis of some absorbers operating under various conditions. Influence of various operating parameters is discussed including gas and liquid compositions, liquid pre-cooling, transfer coefficients and flow rates. The new formulation would provide a convenient tool in the analysis of gas–liquid contact devices in general.

14/02848 Effective purge method with addition of hydrogen on the cathode side for cold start in PEM fuel cell

Kim, S. I. *et al. International Journal of Hydrogen Energy*, 2013, 38, (26), 11357–11369.

The purge process is essential for successful cold start of polymer electrolyte membrane (PEM) fuel cell vehicles during winter, and it plays an important role in the removal of the residual water inside the fuel cell in a short time. In this study, a new purge method is introduced by adding a small amount of hydrogen to the cathode gas flow in order to increase the purge performance. The experimental results demonstrate that the hydrogen addition purge method is very effective in removing the residual water near the catalyst layer. The water removal is verified by measuring the resistance of the fuel cell, dew point temperature of the outlet purge gas, and weights of the membrane electrolyte assembly and gas diffusion layer (GDL). In addition, the image of the GDL after the purge process is captured to show the advantage of the hydrogen addition purge method. Cold start experiments are also conducted after the optimal purge process. It is also found that the degradation of the catalyst layer is not serious after the hydrogen addition purge process.

14/02849 Effects of high-order nonlinearity and rotation on the fission of internal solitary waves in the South China Sea

Zhang, S.-w. and Fan, Z.-s. *Journal of Hydrodynamics, Ser. B*, 2013, 25, (2), 226–235.

A variable coefficient, rotation-modified extended Kortweg–de Vries (KdV) model is applied to the study of the South China Sea (SCS), with focus on the effects of the high-order (cubic) non-linearity and the rotation on the disintegration process of large-amplitude (170 m) internal solitary waves (ISWs) and the semi-diurnal internal tide propagating from the deep basin station to the slope and shelf regions in a continuously stratified system. The numerical solutions show that the high-order non-linearity significantly affects the wave profile by increasing the wave amplitude and the phase speed in the simulated area. It is shown that the initial KdV-type ISW will decay faster when the rotation dispersion is considered, however the wave profile does not change significantly and the rotation effect is not important. The simulations of the semi-diurnal internal tide indicate that the phase of the wave profile is shifted earlier when the rotation effect is included. A solitary wave packet emerges on the shelf, and the wave speed is also greater when considering the rotation dispersion. In addition, the effects of the background currents are discussed further in this paper. It is found that the background currents generally change the magnitude and occasionally change the sign of the non-linear coefficients in the northern SCS.

14/02850 Effects of individual climatic parameters on the infrared thermography of buildings

Lehmann, B. *et al. Applied Energy*, 2013, 110, 29–43.

Infrared thermography is an affordable, fast, and hence widespread, method to detect temperature distributions on the external surfaces of buildings. The interpretation of obtained thermal images requires the knowledge of the status of a multitude of climatic parameters preceding the thermography investigation. The length of the adequate time interval back in the climatic history depends on the thermal properties of the investigated building façade. Based on thermography of an old building with insulated and non-insulated façades, equipped with temperature sensors and a nearby meteorological station, a numerical study has been carried out to quantify the individual influence of parameters such as air and sky temperature, wind, solar irradiation, thermal transmittance (*U*-value) and emissivity on the evaluation of thermal images. Subsequently, an in-depth numerical study is carried out to determine the minimum climatic history needed to correctly interpret the thermal images of various constructions having different thermal performance characteristics.

14/02851 Engineering challenges of ocean liming

Renforth, P. *et al. Energy*, 2013, 60, 442–452.

The relationship between the level of atmospheric CO_2 (carbon dioxide) and the impacts of climate change is uncertain, but a safe concentration may be surpassed this century. Therefore, it is necessary to develop technologies that can accelerate CO_2 removal from the atmosphere. This paper explores the engineering challenges of a technology that manipulates the carbonate system in seawater by the addition of calcium oxide powder (CaO; lime), resulting in a net sequestration of atmospheric CO_2 into the ocean (ocean liming; OL). Every tonne of CO_2 sequestered requires between 1.4 and 1.7 t of limestone to be crushed, calcined, and distributed. Approximately 1 t of CO_2 would be created from this activity, of which >80% is a high purity gas ($pCO_2 > 98\%$) amenable to geological storage. It is estimated that the thermal and electrical energy requirements for OL would be 0.6–5.6 and 0.1–1.2 GJ $tCO_2{}^{-1}$ captured respectively. A preliminary economic assessment suggests that OL could cost approximately US$72–159 t^{-1} of CO_2. The additional CO_2 burden of OL makes it a poor alternative to point source mitigation. However, it may provide a means to mitigate some diffuse emissions and reduce atmospheric concentrations.

14/02852 Fatigue life prediction under variable amplitude axial–torsion loading using maximum damage parameter range method

Chen, H. *et al. International Journal of Pressure Vessels and Piping*, 2013, 111–112, 253–261.

This paper deals with the problem of multiaxial fatigue life assessment under variable amplitude axial–torsion loading. A maximum damage parameter range (MDPR) reversal counting method is proposed to predict fatigue life under variable amplitude multiaxial loading. First, a multiaxial fatigue damage parameter is selected for a given multiaxial loading time history. Then, a damage parameter range time history can be calculated. Finally, based on the MDPR method, fatigue life can be predicted by correlating with multiaxial fatigue damage model and the Miner–Palmgren damage rule. The proposed method is evaluated with experimental data of the 7050-T7451 aluminium alloy and En15R steel under variable amplitude multiaxial loading. The results demonstrated that the proposed method can provide satisfactory prediction.

14/02853 First and second law multidimensional analysis of a triple absorption heat transformer (TAHT)

Donnellan, P. *et al. Applied Energy*, 2014, 113, 141–151.

In this paper, a rigorous multi-dimensional analysis is conducted on a triple absorption heat transformer (TAHT) using the working fluids water and lithium bromide (LiBr). A full factorial design is created which determines the most influential factors affecting the system's coefficient of performance, exergetic coefficient of performance, flow ratio and total exergy destruction. The aim is to draw general conclusions which may be adopted into any such TAHT cycle and not simply be specific to any one scenario. Accordingly, the paper analyses the position of each variable across its thermodynamically available range instead of the traditional selection of arbitrary temperatures. It is found that in general the condensation temperature and the pinch heat transfer gradient selected have the greatest effect, and that these should be minimized in all situations. There exist points of optimum for the temperatures of the two absorber–evaporators within the cycle, however the evaporation temperature has conflicting effects for different dependent variables, and must therefore be selected based on an economic analysis. The results of this study also show that the generator is the source of the largest exergy destruction in the cycle, followed by the two absorber–evaporators.

14/02854 High-speed imaging of biomass particles heated with a laser

Carlsson, P. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 278–286.

In this study two types of lignocellulosic biomass particles, European spruce and American hardwood (particle sizes from 100 to 500 µm) were pyrolysed with a continuous wave 2 W Nd : YAG laser. Simultaneously a high-speed camera was used to capture the behaviour of the biomass particle as it was heated for about 0.1 s. Cover glasses were used as a sample holder which allowed for light microscope studies after the heating. Since the cover glasses are not initially heated by the laser, vapours from the biomass particle are quenched on the glass within about one particle diameter from the initial particle. Image processing was used to track the contour of the biomass particle and the enclosed area of the contour was calculated for each frame. The main observations are: there is a significant difference between how much surface energy is needed to pyrolyse the spruce (about 75% more) compared to the hardwood. The oil-like substance which appeared on the glass during the experiment is solid at room temperature and shows different levels of transparency. A fraction of this substance is water soluble. A brownish coat is seen on the unreacted biomass. The biomass showed insignificant swelling as it was heated. The biomass particle appears to melt and boil at the front that is formed between the laser beam and the biomass particle. The part of the particle that is not subjected to the laser beam seems to be unaffected.

14/02855 Image-based thermographic modeling for assessing energy efficiency of buildings façades

González-Aguilera, D. *et al. Energy and Buildings*, 2013, 65, 29–36.

This paper describes a new approach for image-based modelling using thermographic images and applied to efficiency energy studies of building facades. The approach is automatic and allows one to obtain thermographic three-dimensional models and orthoimages, which can be used to assess energy efficiency of building facades. The classical photogrammetry approach is reinforced and combined with computer vision algorithms, especially for the processes of image matching and dense surface generation, so that they have a robust performance with thermographic images. Experimental results presented here demonstrate the capability of the proposed approach using the Polytechnic Advanced School of Avila in Spain as a case study.

14/02856 Inverse cycles modeling without refrigerant property specification

Scarpa, F. *et al. International Journal of Refrigeration*, 2013, 36, (6), 1716–1729.

A method is presented and tested which, implemented along with a lumped dynamical model of an inverse cycle, allows for the description of the system with very simple mathematical tools, without any need to possess information about the thermophysical properties of the refrigerant fluid operating in the cycle. The algorithm, based on the fluid independent Carnot cycle, is applied both to a household refrigerator and to a direct expansion, variable capacity, solar-assisted heat pump (DX-SAHP). The validity of the approach is established by comparing the numerical results of the proposed simplified approach to transient and time averaged data based on consolidated thermodynamic-cycle simulators which make use of full standard fluid properties description. Simulations comparisons confirm the ability of the proposed model to closely adhere to the dynamic behaviour of the considered devices and disclose the opportunity to develop inverse-cycle models so simple to be easily embedded, along with their sensitivity features, in cheap model-based regulators and transient control strategy developments.

14/02857 Lit environments quality: a software for the analysis of luminance maps obtained with the HDR imaging technique

Bellia, L. *et al. Energy and Buildings*, 2013, 67, 143–152.

Energy performance of lighting systems has assumed a significant role in the assessment of buildings' consumptions and consequently lighting design is aimed to reduce installed power but at the same time to achieve an excellent lighting quality both for visual and health purposes. Lighting design is nowadays essentially based on illuminance values on visual tasks and surrounding areas, but today designers' and researchers' interest is focused on the analysis of luminance maps obtained through video luminance meters or with numeric simulation tools. Luminance maps availability focus the attention on a more accurate study of the light reaching the eyes (luminance), rather than on the light that arrives on surfaces (illuminance). However, luminance values, based on photopic sensitivity, do not always adequately describe the quality of a lit environment and how it is perceived; therefore it is necessary to consider parameters like brightness or equivalent luminance. The first part of this work describes primary factors that influence lit environments' perception along with the main available luminance–brightness relations. Moreover a software for the luminance maps' analysis is described with the goal of finding and testing the most significant parameters for the lit environment's description, both for comfort and energy purposes.

14/02858 Online training algorithms based single multiplicative neuron model for energy consumption forecasting

Wu, X. *et al. Energy*, 2013, 59, 126–132.

Although traditional approaches can yield accurate forecasting results of energy consumption, they may suffer from several limitations such as the need for large dataset and the linear assumption. Two novel hybrid dynamic approaches, which are based on the single multiplicative neuron (SMN) model and the iterated non-linear filters, have been proposed for forecasting energy consumption with small dataset and non-linearity in this study. The forecasting models are established by using the weights and the biases of SMN model to present the state vector and the output of SMN model to present the observation equation, and the input vector to the SMN model is composed of the known energy consumption values with a rolling mechanism. The SMN model has advantages of better approximation capabilities, simpler network structures and faster learning algorithms. The non-linear filters can deal with additive noises and can update model parameters when a new observation data arrives due to their iterative algorithm structure. Two case studies of energy consumption have been used to demonstrate the reliability of the proposed models, and the experimental results have indicated that the proposed approaches outperform existing models in forecasting energy consumption.

14/02859 Polarization phenomena of hydrogen-rich gas in high-permeance Pd and Pd–Cu membrane tubes

Chen, W.-H. *et al. Applied Energy*, 2014, 113, 41–50.

Concentration polarization, a retarding effect on hydrogen permeation across a membrane, will affect the performance of hydrogen separation. To recognize the concentration polarization behaviour of hydrogen-rich gas in high-permeance membrane tubes, three palladium-based membranes with two pure palladium (Pd) membranes and one Pd–Cu alloy membrane are tested. Three important parameters, consisting of the H_2 partial pressure difference, the flow rate at the exit of the retentate side and the H_2 concentration in the feed gas mixture (H_2+N_2), are taken into account. A comparison to pure H_2 permeation suggests that the concentration polarization is clearly exhibited when the gas mixture is fed. Decreasing the H_2 concentration in the feed gas tends to deteriorate the polarization phenomenon. The sensitivity of polarization to H_2 concentration is higher when its concentration in the feed gas is larger. For the gas mixtures with 50 and 75 vol% of H_2, the permeances of the membranes are reduced by one to two orders of magnitude. The permeances of the membranes are also affected a bit when the H_2 partial pressure difference or the flow rate is altered.

14/02860 Predicting building ages from LiDAR data with random forests for building energy modeling

Tooke, T. R. *et al. Energy and Buildings*, 2014, 68, 603–610.

This study examines the use of airborne light detection and ranging (LiDAR) data to augment the prediction of building age and energy performance for numerous buildings using a random forests machine learning approach. Analysis is conducted for a residential neighbourhood in Vancouver, Canada. Four separate models are developed to represent the increasing sophistication of spatial data available to municipalities. Results indicate that the random forests model using only LiDAR-derived building attributes predicts age with an average error (root-mean-square error) of 16.8 years and 33.5% of the variance explained. When all attributes are combined from the various datasets the predictive capacity of the model is increased by 20% and the average error reduced to 15.8 years. Furthermore, examination of variable importance suggests that while mean building height derived from the LiDAR data is the most important attribute predicting age, the three subsequently ranked variables relate to non-LiDAR based attributes. Discussion is given to observable trends between select predictor variables and building age, and to the implications for building energy modelling and simulation efforts.

14/02861 Stress-displacement solution for a lined vertical borehole due to non-axisymmetric in situ stresses

Lu, A.-Z. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2013, 57, 64–74.

By using the semi-inverse method, an elastic plane stress solution of a lined vertical borehole in an isotropic ground due to non-axisymmetric *in situ* loads is presented. As two extreme cases, pure bond and pure slip boundary conditions, along the liner/ground interfaces have been implemented. The effect of elastic modulus of liner and ground and thickness of liner upon the stresses and displacements are analysed. The result indicates that soft liner may alleviate the normal stress and shear stress acting on the liner outer surface. The maximum tangential compressive stresses and tensile stresses in liner for two extreme boundary cases occur on the inner and outer boundaries of liner. The shear stress reaches the maximum value at $\theta = 45^\circ$ and the harder the liner, the greater the maximum value.

14/02862 Study on the performances of SnS heterojunctions by numerical analysis

Xu, J. and Yang, Y. *Energy Conversion and Management*, 2014, 78, 260–265.

Semiconducting SnS heterojunctions have been used as solar cell structures. In an effort to study the photovoltaic (PV) properties of different SnS heterojunctions, in this work, the CdS/SnS, ZnS/SnS, ZnO/SnS, a-Si/SnS, and SnS/c-Si heterojunctions were studied by numerical analysis. The calculated results show that the ZnS/SnS heterojunction has the highest conversion efficiency. The SnS thin film has different roles depending on another material. The heterojunction structure will affect the window and absorption properties. Less absorption in the window layer and reduced photogenerated carrier barrier in the heterojunction interface will lead to improved PV properties. The PV properties can be further enhanced by adjusting the thickness. The calculated results provide a guide to the design and fabrication of SnS heterojunction solar cells.

14/02863 The working principle of a vortex tube

Xue, Y. *et al. International Journal of Refrigeration*, 2013, 36, (6), 1730–1740.

The generation of cold and hot streams from a single injection in a vortex tube has been investigated by many researchers, aiming to define the primary reasons for the separation. This paper reports a detailed description of the flow behaviour inside a vortex tube and addresses the mechanism for the generation of cold and hot streams in a vortex tube, which is confirmed by different experimental methodologies, including visualization of the flow structure in a water-operated vortex tube, and measurement of velocity profiles in both water- and air-operated vortex tubes. Estimation of the theoretical temperature drop based on the pressure gradient of a forced vortex flow is addressed in this paper, and good agreement with the experimental results was observed. Exergy analysis of the flow properties in an air-operated vortex tube indicates that there is no outward energy transfer in the hot region of the vortex tube. Furthermore, the governing factor for the temperature rise is attributed to the stagnation and mixture of the flow structure. Based on the proposed mechanism, the predicted performance of the vortex tube with variable geometrical parameters, were congruent with the experimental results, underpinning the validity of the proposed mechanism.

14/02864 Wave propagation in a piezoelectric solid bar of circular cross-section immersed in fluid

Ponnusamy, P. *International Journal of Pressure Vessels and Piping*, 2013, 105–106, 12–18.

Wave propagation in a piezoelectric solid bar of circular cross-section immersed in fluid is discussed using three-dimensional theory of piezoelectricity. The equations of motion of the cylinder are formulated using the constitutive equations of a piezoelectric material. The equations of motion of the fluid are formulated using the constitutive equations of an inviscid fluid. Three displacement potential functions are introduced to uncouple the equations of motion, electric conduction. The frequency equation of the coupled system consisting of cylinder and fluid is developed under the assumption of perfect-slip boundary conditions at the fluid–solid interfaces. The frequency equations are obtained for longitudinal and flexural modes of vibration and are studied numerically for PZT-4 material bar immersed in fluid. The computed non-dimensional wave numbers are presented in the form of dispersion curves. The secant method is used to obtain the roots of the frequency equation.

Fuel cell technology

14/02865 A review of cellulosic microbial fuel cells: performance and challenges

Ahmad, F. *et al. Biomass and Bioenergy*, 2013, 56, 179–188.

Cellulosic biomass, in the form of lignocellulosic materials, is a renewable and readily accessible source of organic substrate for microbial fuel cells (MFCs). The performances of cellulosic MFCs were compared on a common basis and with respect to the properties of the different cellulosic substrate each utilized. Moreover, the different experimental design approaches employed to overcome performance limitations of cellulosic MFCs were evaluated. Comparison of the mean peak currents and mean peak power densities revealed that MFCs run on cellulose were electrically outperformed by those run on starch but not those run on chitin. It was further observed that coulombic efficiency, the measure of effective substrate utilization for current generation, was greatest for soluble polysaccharide substrates, whether starch or cellulose. For insoluble polysaccharide substrates, coulombic efficiency decreased as the degree of polymerization increased. These and other conclusions indicate that both substrate accessibility and effective substrate utilization are important factors for electrical performance of cellulosic MFCs. The evaluation exposes the need for more thorough and systematic design and analysis of MFC experiments employing cellulose and other polysaccharides as substrates.

14/02866 Accelerating parameter identification of proton exchange membrane fuel cell model with ranking-based differential evolution

Gong, W. and Cai, Z. *Energy*, 2013, 59, 356–364.

Parameter identification of proton exchange membrane (PEM) fuel cell model is a very active area of research. Generally, it can be treated as a numerical optimization problem with complex non-linear and multi-variable features. Differential evolution (DE), which has been successfully used in various fields, is a simple yet efficient evolutionary algorithm for global numerical optimization. In this paper, with the objective of accelerating the process of parameter identification of PEM fuel cell models and reducing the necessary computational efforts, the authors first present a generic and simple ranking-based mutation operator for the DE algorithm. Then, the ranking-based mutation operator is incorporated into five highly-competitive DE variants to solve the PEM fuel cell model parameter identification problems. The main contributions of this work are the proposed ranking-based DE variants and their application to the parameter identification problems of PEM fuel cell models. Experiments have been conducted by using both the simulated voltage–current data and the data obtained from the literature to validate the performance of the approach. The results indicate that the ranking-based DE methods provide better results with respect to the solution quality, the convergence rate, and the success rate compared with their corresponding original DE methods. In addition, the voltage–current characteristics obtained by this approach are in good agreement with the original voltage–current curves in all cases.

14/02867 Effective removal and transport of water in a PEM fuel cell flow channel having a hydrophilic plate

Qin, Y. *et al. Applied Energy*, 2014, 113, 116–126.

Effective removal and transport of water in the flow channel of a proton exchange membrane (PEM) fuel cell (PEMFC) is significantly important to the critical water management in PEMFCs. In this study, the process of water removal and transport is investigated numerically by using the volume-of-fluid method for a flow channel having a hydrophilic plate in the middle of the channel. The results show that the liquid water droplet on the membrane-electrode assembly (MEA) surface can be removed effectively, and the removal process is facilitated significantly by the hydrophilic plate which should have a surface contact angle larger than the bottom channel surface but less than the MEA surface. Once the liquid water contacts the plate, it is detached from the MEA surface, and transported to the channel surface along the plate surface; whereas without the plate the water droplet is transported along the MEA surface under the same flow condition. The pressure drop associated with the flow in the channel can be reduced substantially by the presence of the plate due to a characteristic change in the water removal and transport process, when compared to the pressure drop in a conventional flow channel or a channel with a needle shown in literature. The wettability, the length and the height of the plate all can have an impact on the water transport and dynamics as well as the associated pressure drop in the flow channel. A parametric study is carried out to determine the optimal values for the surface contact angle, the length and height of the plate.

14/02868 Financial analysis of utility scale photovoltaic plants with battery energy storage

Rudolf, V. and Papastergiou, K. D. *Energy Policy*, 2013, 63, 139–146.

Battery energy storage is a flexible and responsive form of storing electrical energy from renewable generation. The need for energy storage mainly stems from the intermittent nature of solar and wind energy sources. System integrators are investigating ways to design plants that can provide more stable output power without compromising the financial performance that is essential for investors. Network operators on the other side set stringent requirements for the commissioning of new generation, including preferential terms for energy providers with a well-defined generation profile. The aim of this work is to highlight the market and technology drivers that impact the feasibility of battery energy storage in a utility-scale solar photovoltaic project. A simulation tool combines a battery cycling and lifetime model with a solar generation profile and electricity market prices. The business cases of the present market conditions and a projected future scenario are analysed.

14/02869 Functional nanoceramics for intermediate temperature solid oxide fuel cells and oxygen separation membranes

Sadykov, V. *et al. Journal of the European Ceramic Society*, 2013, 33, (12), 2241–2250.

This paper reviews the results of research aimed at design and characterization of mixed ionic–electronic conducting perovskite–fluorite nanocomposite oxide ceramics. Nanocrystalline oxides were prepared via Pechini route, nanocomposites – via ultrasonic dispersion of their mixture in organic solvents with addition of surfactants. Genesis of the real structure of nanocomposites at sintering by conventional as well as advanced (microwave or e-beam treatment) techniques was studied in details by structural methods. Applied preparation procedures ensured nano-sizes of perovskite/fluorite domains even in dense ceramics and a high spatial uniformity of their distribution. Redistribution of elements between perovskite and fluorite domains without formation of new phases was revealed. Characterization of nanocomposite transport properties by oxygen isotope heteroexchange and conductivity or weight relaxation demonstrated that perovskite–fluorite interfaces are paths for fast oxygen diffusion. Best perovskite–fluorite combinations tested as cathode layers or dense oxygen separation layers in asymmetric supported membranes demonstrated performance promising for the practical application.

14/02870 Lagooning microbial fuel cells: a first approach by coupling electricity-producing microorganisms and algae

Lobato, J. *et al. Applied Energy*, 2013, 110, 220–226.

The paper focused on the start-up and performance characterization of a new type of microbial fuel cell (MFC), in which an algae culture was seeded in the cathodic chamber to produce the oxygen required to complete the electrochemical reactions of the MFC, thus circumventing the need for a mechanical aerator. The system did not use mediators or high-cost catalysts and it can be started-up easily using a straightforward three-stage procedure. The start-up consists of the separate production of the electricity-producing microorganisms and the algae cultures (stage I), replacement of the mechanical aeration system by the algae culture (stage II) and a change in the light dosage from a continuous input to a dynamic day/night profile. The MFC was operated under a regime of 12 h light and 12 h dark and was also operated in batch and continuous substrate-feeding modes. The same cell voltage was achieved when the cathode compartment was operated with air supplied by aerators, which means that this configuration can perform as well as the traditional one. The results also show the influence of both the organic load and light irradiation on electricity production and demonstrate that this type MFC is a robust and promising technology that can be considered as a first approach to perform a lagooning wastewater treatment with microbial fuel cells.

14/02871 Load-following mode control of a standalone renewable/fuel cell hybrid power source

Bizon, N. *Energy Conversion and Management*, 2014, 77, 763–772.

A hybrid power source (HPS), fed by renewable energy sources (RESs) and fuel cell (FC) sources, with an energy storage device (ESS) to be suitable for distributed generation (DG) applications, is proposed. The RESs could be a combination of photovoltaic (PV) panels and wind turbines (WT) based on common DC-bus, which are used as the primary DC source. The FC operates as a backup, feeding only the insufficiency power from the RESs based on the load-following strategy. The battery/ultracapacitor hybrid ESS operates as an auxiliary source for supplying the power deficit based on dynamic power balance strategy (the transient power – mainly via the ultracapacitors stack, and the steady-state power – mainly via the FC and batteries stack). If the FC stack is designed and operates based on average load-following strategy, then the ESS will operate in charge-sustaining mode during a load cycle. This feature permits to optimize the batteries stack capacity and extend its life time as well. The ultracapacitor stack can be designed considering the peaks of RESs power on DC-bus and the imposed window for its state of charge. This FC/RES/ESS HPS is ideal to be used for standalone plug-in charge station or as DG system grid connected. In the last case, which is not analysed in this paper, the energy management unit that communicates with smart grid will establish the moments to match the HPS power demand with grid supply availability, stabilizing the grid. Using load and RES power profiles that have a higher dynamic than in reality, the HPS operation is shown based on an analytical analysis and the appropriate Matlab/Simulink simulations.

14/02872 Low platinum, high limiting current density of the PEMFC (proton exchange membrane fuel cell) based on multilayer cathode catalyst approach

Fofana, D. *et al. Energy*, 2014, 64, 398–403.

Novel multilayer cathode electrode structures for proton exchange membrane fuel cells (PEMFCs) based on the sputtering technique were developed to provide high performance with low loading Pt of 0.05 mg/cm^2 compared to the standard membrane electrode assembly (MEA) cathode (~0.2–0.3 mg/cm^2). Different configurations of the cathode catalyst layer were made by altering Pt and carbon–Nafion (CN) ink carefully prepared on a gas diffusion layer containing microporous layer. The performances of PEMFC containing the multilayer electrodes were compared based on their measured polarization curves. Higher limiting current densities were achieved compared to standard MEA with Pt loading of 0.2 mg/cm^2 both at the cathode and the anode sides. Limiting current densities above 1.1, 1.2 and 1.4 A/cm^2 were reached whereas maximum powers were in the range of 500 and 600 mW/cm^2. The good performance obtained could be due to the structural improvement which has contributed to a better catalyst utilization compared to conventional methods. A CN loading below to 0.24 mg/cm^2 between each layer is preferred for the multilayer electrode.

14/02873 Manufacture of a non-stoichiometric LSM cathode SOFC material by aqueous tape casting

Gómez, L. *et al. Journal of the European Ceramic Society*, 2013, 33, (6), 1137–1143.

This work deals with the manufacture of non-stoichiometric strontium-doped lanthanum manganite (LSM) as a cathode material by aqueous colloidal processing. This requires some knowledge of the processability and sinterability of this material. The stability of aqueous suspensions of a fine non-stoichiometric LSM powder was studied by measuring the zeta potential as a function of pH and deflocculant content. Concentrated suspensions were prepared to solids loadings as high as 50 vol.%. The best dispersing conditions and the influence of binders and tape casting performance were determined by means of rheological measurements. LSM cathode tapes were characterized in the green state and after sintering at 1500 °C/2 h, leading to high density compacts. Maximum sintering rate is achieved at 1350 °C. Once the sintering behaviour is known a porous material can be easily designed using a sintering temperature compatible with the other components of the semi-cell.

14/02874 Numerical analysis of optimal performance of planar electrode supported solid oxide fuel cell at various syngas flow rates

Wang, Y. *et al. Energy Conversion and Management*, 2014, 77, 637–642.

With the gradual scarcity of fossil fuels and the emergency demand of greenhouse gas emission reduction, coal, as the major energy source of China for a long time in the future, should be used efficiently and cleanly. The integrated gasification fuel cell (IGFC) hybrid power generation system is a promising clean coal utilization technology. In order to improve the performance of IGFC hybrid power generation system, the optimal performance of solid oxide fuel cells (SOFCs) at different flow rates of syngas were numerically studied in this work. The performance curves of SOFCs at various syngas flow rates were obtained. The results show that the temperature in the channel of SOFC is decreasing linearly with the increase of the syngas flow rate, when the average current density is constant. With the increase of syngas flow rate, the output voltage is reduced, but the optimal output power and the possible optional range of current density will increase. Under different mass flow rates, the fuel utilization at the optimal output power density decreases with increase of syngas flow rate. The polynomial function between the fuel utilization at optimal output power density and the mass flow rate of syngas was obtained.

14/02875 On the influence of silica type on the structural integrity of dense $La_{9.33}Si_2Ge_4O_{26}$ electrolytes for SOFCs

Alves, C. *et al. Journal of the European Ceramic Society*, 2013, 33, (12), 2251–2258.

Apatite-type rare earth based oxides, such as R-doped lanthanum oxides of general formula $La_{9.33}(RO_4)_6O_2$ with R = Ge, Si, exhibit high ionic conductivity and low activation energy at moderate temperatures, when compared to the yttria-stabilized zirconia electrolyte making them potential materials to be used in the range 500–700 °C, for intermediate temperature solid oxide fuel cells (IT-SOFCs). In this study, dense oxyapatite-based $La_{9.33}Si_2Ge_4O_{26}$ electrolytes have been successfully prepared either by electrical sintering at 1400 °C or microwave hybrid sintering at 1350 °C for 1 h from La_2O_3, SiO_2 and GeO_2 powders dry milled at 350 rpm for 15 h in a planetary ball mill. The densification behaviour of the apatite-type phase synthesized by mechanical alloying was found to be dependent on the grade of SiO_2 used: either pre-milled quartz powder or amorphous nanosized fumed silica. The influence of the silica type on the $La_{9.33}Si_2Ge_4O_{26}$ integrity was assessed by dynamic Young's modulus, microhardness and indentation fracture toughness measurements. A good correlation between the degree of densification (as observed by scanning electron microscopy with energy dispersive X-ray spectroscopy) and the resulting mechanical properties could be established. Pre-milling of quartz powder has favoured higher densification rates to be attained suggesting that both Fe content, resulting from the dry milling (as determined by particle-induced X-ray emission analyses) and crystallinity of SiO_2 do promote densification of these electrolytes thereby improving their structural integrity.

14/02876 Performance optimum analysis of an irreversible molten carbonate fuel cell–Stirling heat engine hybrid system

Chen, L. *et al. Energy*, 2014, 64, 923–930.

A new hybrid system mainly consists of a molten carbonate fuel cell (MCFC) and a Stirling heat engine is established, where the Stirling heat engine is driven by the high-quality waste heat generated in the MCFC. Based on the electrochemistry and non-equilibrium thermodynamics, analytical expressions for the efficiency and power output of the hybrid system are derived by taking various irreversible losses into account. It shows that the performance of the MCFC can be greatly enhanced by coupling a Stirling heat engine to further convert the waste heat for power generation. By employing numerical calculations, not only the influences of multiple irreversible losses on the performance of the hybrid system are analysed, but also the impacts of some operating conditions such as the operating temperature, input gas compositions and operating pressure on the performance of the hybrid system are also discussed. The investigation method in the present paper is feasible for some other similar energy conversion systems as well.

14/02877 Performance restoration of direct methanol fuel cells in long-term operation using a hydrogen evolution method

Mehmood, A. and Ha, H. Y. *Applied Energy*, 2014, 114, 164–171.

A detailed study has been carried out to investigate the changes taking place in the electrodes of a direct methanol fuel cell (DMFC) on their exposure to the hydrogen gas that is electrochemically evolved *in situ* in the electrodes. It is found that the individual, as well as the combined, H_2 evolution treatment of both the anode and the cathode for a short amount of time causes a substantial improvement in the cell performance, which is attributed to their improved catalytic activities. The exposure of Pt and PtRu catalysts to evolved H_2 is beneficial in reducing the surface oxides that are formed during DMFC operation. The performance losses originating from the catalyst oxidation in a continuous operation are successfully recovered by the H_2 evolution method, and the DMFC has experienced a voltage loss of only 15 mV during a 1383 h durability test. These results show the effectiveness of using the H_2 evolution method to reduce catalyst oxides and recover the performance losses of a DMFC. Various physical and electrochemical analyses are carried out to fully understand the mechanism and the consequences of the H_2 evolution treatment in DMFCs.

15 ENVIRONMENT

Pollution, health protection, applications

14/02878 A dynamic Bayesian networks modeling of human factors on offshore blowouts

Cai, B. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (4), 639–649.

An application of dynamic Bayesian networks for quantitative risk assessment of human factors on offshore blowouts is presented. Human error is described using human factor barrier failure (HFBF), which consists of three categories of factors, including individual factor barrier failure (IFBF), organizational factor barrier failure (OFBF) and group factor barrier failure (GFBF). The structure of human factors is illustrated using pseudo-fault tree, which is defined by incorporating the intermediate options into fault tree in order to eliminate the binary restriction. A methodology of translating pseudo-fault tree into Bayesian networks and dynamic Bayesian networks taking repair into consideration is proposed and the propagation is performed. The results show that the human factor barrier failure probability only increases within the first two weeks and rapidly reaches a stable level when the repair is considered, whereas it increases continuously when the repair action is not considered. The results of mutual information show that the important degree sequences for the three categories of human factors on HFBF are: GFBF, OFBF and IFBF. In addition, each individual human factor contributes different to the HFBF, those which contribute much should given more attention in order to improve the human reliability and prevent the potential accident occurring.

14/02879 Achieving carbon emission reduction through industrial & urban symbiosis: a case of Kawasaki

Dong, H. *et al. Energy*, 2014, 64, 277–286.

Industry and fossil fuel combustion are the main sources for urban carbon emissions. Most studies focus on energy consumption emissions reduction and energy efficiency improvements. Material saving is also important for carbon emissions reduction from a lifecycle perspective. Industrial symbiosis (IS) and urban symbiosis (U_rS) have been effective since both of them encourage by-products exchange. However, quantitative carbon emissions reduction evaluations on applying them are lacking. Consequently, the purpose of this paper is to fill such a gap through a case study in Kawasaki eco-town, Japan. A hybrid life cycle analysis model was employed to evaluate to the lifecycle carbon footprint. The results show that lifecycle carbon footprints with and without IS and U_rS were 26.66 and 30.92 Mt CO_2e, respectively. The carbon emissions efficiency was improved by 13.77% with the implementation of IS and U_rS. The carbon emissions reduction was mainly from the iron and steel, cement and paper-making industries, with figures of 2.76, 1.16 and 0.34 Mt CO_2e, respectively. Reuse of scrap steel, blast-furnace slag and waste paper are all effective measures for promoting carbon emissions reductions. Policy implications on how to further promote IS and U_rS are also presented.

14/02880 Analysis of the Bingaman clean energy standard proposal

Paul, A. *et al. Resource and Energy Economics*, 2014, 36, (1), 113–129.

A clean energy standard (CES) is a flexible approach to encouraging a cleaner technology mix for electricity production. The most recent federal CES proposal from former Senator Bingaman would transform the way electricity is produced and result in substantial reductions in CO_2 emissions with small national average electricity price effects through 2025. After 2025, electricity prices would increase substantially. The alternative compliance payment (ACP) for clean energy credits will be binding, so actual deployment of clean energy will fall short of the intended targets, and cumulative emissions reductions by 2035 will be 12% smaller than they would be without an ACP. The small utility exemption from the CES requirements equates to roughly $29 billion in avoided electricity expenditures by the customers of exempted utilities in 2035 alone. Excluding power generated by existing nuclear and hydroelectric facilities from CES compliance responsibility raises electricity prices in competitive regions to the benefit of owners of existing nuclear and hydroelectric capacity.

14/02881 Can social influence drive energy savings? Detecting the impact of social influence on the energy consumption behavior of networked users exposed to normative eco-feedback

Jain, R. K. *et al. Energy and Buildings*, 2013, 66, 119–127.

Eco-feedback systems provide a significant opportunity to reduce energy consumption. Previous studies have demonstrated a link between providing users with socially contextualized feedback on their energy consumption and reductions in energy use. Yet, the question of whether social influences drive energy savings remains unanswered. This study develops an algorithmic approach based on stochastic and social network test procedures to assess whether social influence impacts energy consumption behaviour and apply the approach to an empirical data set of users exposed to unit-level socially contextualized feedback. The authors conducted a 47-day empirical experiment in a New York city midrise residential building occupied by students to capture energy consumption and user interaction data for participants in self-identified social networks. Social influence effects on peer network energy consumption were successfully characterized and isolated using adapted social network tests. These results indicate that future research should focus on how social influence and social networks can be leveraged to maximize savings in energy conservation programmes.

14/02882 Decomposition of energy-related GHG emissions in agriculture over 1995–2008 for European countries

Robaina-Alves, M. and Moutinho, V. *Applied Energy*, 2014, 114, 949–957.

The objective of this work is to identify the effects in which the intensity of greenhouse gas (GHG) emissions (EI) in agriculture can be broken down and analysed, as well as their evolution and which of them has more importance in determining the intensity of emissions in agriculture. For that, the authors used the 'complete decomposition' technique in the 1995–2008 period, for a set of European countries. The change of EI can be decomposed into five effects: (i) the changes in GHG emissions compared to the fossil fuels consumption (EF effect), (ii) the changes in fossil fuels consumption compared to the use of nitrogen in agriculture (FN effect), (iii) the change in use of nitrogen in agriculture per hectare of utilized agricultural area (NA effect), (iv) the change in utilized agricultural area per worker (AL effect) and the inverse of average labour productivity in agriculture (LVA effect). It is shown that in most countries studied, there was an increase in agriculture emissions intensity, and in only five countries this variable declined. The greatest decrease was seen in Italy (−0.01), while the highest increases were found in the Netherlands (+0.394), Belgium (+0.277) and Luxembourg (+0.203). NA effect and LVA effect were the ones that had a greater contribution to the variation of emissions intensity. In the countries in which the variation of EI is positive, the effect of NA is the main one responsible for this increase (for instance 100%, 118.6% and 104% for Netherlands, Belgium and Luxembourg, respectively), which means that the use of nitrogen per cultivated area is an important factor of emissions. The effect LVA proves to be the most important, specifically in the countries where the change in EI is negative (for instance, 113.9% for Italy). This means that in countries where labour productivity increases (LVA decreases), emissions intensity tends to decrease.

14/02883 Deposition of diesel exhaust particles from various fuels in a cast of human respiratory system under two breathing patterns

Penconek, A. and Moskal, A. *Journal of Aerosol Science*, 2013, 63, 48–59.

Diesel exhaust particles (DEPs) are nanometric aggregates with organic compounds adsorbed on their surface. The compounds are often mutagenic and cytotoxic. Due to their small size DEPs may penetrate into the respiratory tract potentially causing health problems. The aim of this study was to determine the amount of DEPs deposited in the cast of human respiratory system under various breathing conditions. Silicone model of upper and lower airways was attached to artificial lung apparatus (ALA) to generate breathing flow similar to mechanism of mammalian lungs' work. The amount of DEPs deposited in the cast of human respiratory system was established gravimetrically. Deposition efficiency was determined for three types of commercially available diesel fuels under two different breathing pattern conditions. The results showed that the amount of compact DEPs deposited in the respiratory tract is higher than dendrite-like aggregates DEPs from fuel I and III. In addition, fraction of DEPs from fuel II that deposited in the lower airways is the lowest. However, the DEPs deposition is higher if the value of tidal volume and breaths per minute is high – regardless of kind of a fuel. Despite some assumptions – inevitable in case of *in vitro* research – the results of this research showed a distribution of DEPs deposition in a cast of respiratory system, which is a key link between exposure on diesel exhaust fumes and the health effects.

14/02884 Development of a new test system to determine penetration of multi-walled carbon nanotubes through filtering facepiece respirators

Vo, E. and Zhuang, Z. *Journal of Aerosol Science*, 2013, 61, 50–59.

Carbon nanotubes (CNTs) are currently used in numerous industrial and biomedical applications. Recent studies suggest that workers may be at risk of adverse health effects if they are exposed to CNTs. A National Institute for Occupational Safety and Health survey of the carbonaceous nanomaterial industry found that 77% of the companies used respiratory protection. Elastomeric half-mask respirators and filtering facepiece respirators (FFRs) are commonly used. Although numerous respirator filtration studies have been done with surrogate engineered nanoparticles, such as sodium chloride, penetration data from engineered nanoparticles such as CNTs are lacking. The aims of this study were to develop a new CNT aerosol respirator testing system and to determine multi-walled CNT (MWCNT) penetration through FFRs. A custom-designed CNT aerosol respirator testing system (CNT-ARTS) was developed which was capable of producing a sufficient amount of airborne MWCNTs for testing of high efficiency FFRs. The size distribution of airborne MWCNTs was 20–10,000 nm, with 99% of the particles between 25 and 2840 nm. The count median diameter (CMD) was 209 nm with a geometric standard deviation (GSD) of 1.98. This particle size range is similar to those found in some work environments (particles $\leq$6000 nm). The penetration of MWCNTs through six tested FFR models at two constant flow rates of 30 and 85 LPM was determined. Penetration at 85 l/min (0.58–2.04% for N95, 0.15–0.32% for N99, and 0.007–0.009% for P100 FFRs) was greater compared with the values at 30 l/min (0.28–1.79% for N95, 0.10–0.24% for N99, and 0.005–0.006% for P100 FFRs). The most penetrating particle size through all six tested FFR models was found to be in the range of 25–130 and 35–200 nm for the 30 and 85 l/min flow rates, respectively.

14/02885 Economic-environmental energy and reserve scheduling of smart distribution systems: a multiobjective mathematical programming approach

Zakariazadeh, A. *et al. Energy Conversion and Management*, 2014, 78, 151–164.

A stochastic multi-objective economical/environmental operational scheduling method is proposed to schedule energy and reserve in a smart distribution system with a high penetration of wind generation. The proposed multi-objective framework, based on augmented ϵ-constraint method, is used to minimize the total operational costs and emissions and to generate Pareto-optimal solutions for the energy and reserve scheduling problem. Moreover, fuzzy decision making process is employed to extract one of the Pareto-optimal solutions as the best compromise non-dominated solution. The wind power and demand forecast errors are considered in this approach and the reserve can be furnished by the main grid as well as distributed generators and responsive loads. The consumers participate in both energy and reserve markets using various demand response programmes. In order to facilitate small and medium loads participation in demand response programs, a demand response provider aggregates offers for load reduction. In order to solve the proposed optimization model, the Benders decomposition technique is used to convert the large-scale mixed integer non-linear problem into mixed-integer linear programming and non-linear programming problems. The effectiveness of the proposed scheduling approach is verified on a 41-bus distribution test system over a 24-h period.

14/02886 Effects of natural environment on urban household energy usage carbon emissions

Ye, H. *et al. Energy and Buildings*, 2013, 65, 113–118.

Residential households are important contributors to carbon emissions when under rapid urbanization. This study analyses the relationship between urban residential energy usage carbon dioxide emissions and the natural environment in Xiamen, south-east China, using integrated residential data from survey questionnaires and remote sensing and geographical information system techniques. Household social, economic and construction impacts were eliminated by establishing a standardized family and choosing housing units constructed after 2003. Ordinary least squares regression was used to explain the effect of buildings' surrounding natural conditions on urban energy usage carbon dioxide emissions. The results show that urban home energy usage carbon dioxide emissions were reduced by green spaces and water bodies, after building construction and household social and economic impact factors were eliminated. Water bodies show a closer relationship with carbon dioxide emissions than green spaces. These results prove that green spaces and bodies of water are important in residential energy usage carbon dioxide emission reduction. Therefore, better green space and water planning will improve sustainable urban development.

14/02887 Efficiency assessment of key psychometric processes

Ratlamwala, T. A. H. and Dincer, I. *International Journal of Refrigeration*, 2013, 36, (3), 1142–1153.

The study focuses on defining energy and exergy efficiencies based on three different types of approaches. For each of five key psychometric processes, such as heating or cooling, heating with humidification, cooling with dehumidification, evaporative cooling, and adiabatic mixing, parametric studies are carried out. Two efficiencies are newly proposed here in this study, and the third efficiency is taken from the literature for comparison purposes. The results show that for heating process exergy efficiency varies from 0.012 to 0.48 with rise in ambient temperature. Increasing ambient temperature results in variation of exergy efficiency from 0.014 to 0.29 for heating with humidification process. For cooling with dehumidification process exergy efficiency varies from 0.002 to 0.73 with rise in ambient temperature. The exergetic efficiency of evaporative cooling process varies from 0.64 to 0.03 with an increase in ambient temperature. For adiabatic mixing process, exergy efficiency varies from 0.65 to 0.94 with rise in ambient temperature.

14/02888 Energetic and exergetic comparison of the human body for the summer season

Caliskan, H. *Energy Conversion and Management*, 2013, 76, 169–176.

Energy and exergy analyses are performed for the human body in the summer season of Izmir city in Turkey. It is found that the metabolic energy and exergy rates are the major part of the human body's energy generation. However, metabolism energy rate (58.326 W/m^2) is much higher than corresponding exergetic one (1.661 W/m^2). The maximum energy loss of the human body (70.59%) occurs due to heat exchange such as radiation, convection and conduction. On the other hand, the maximum exergy loss of the human body happens due to exhaled humid air (6.393%), while the most of the total exergy is consumed by the human body (90.786%). Thermal comfort condition is also calculated. The predicted mean vote rate is found as 0.028 which means that the thermal sensation of the human body is called as comfortable. Furthermore, the predicted percentage dissatisfied rate is determined to be 5.017% which is low and shows the thermally dissatisfied people percentages.

14/02889 Energy use of households in apartment complexes with different service life

Kim, M. J. *et al. Energy and Buildings*, 2013, 66, 591–598.

Government policies aimed at reducing energy use have focused on technical aspects of building structures, not residents' behaviours in households. However, many studies have argued that residents' behaviours might play a prominent role in the reduction of energy consumption in households. Compared to the impact of buildings' features on energy use, little research exists that considers household characteristics in addition to building features in analysing the effect of residents' behaviours on energy use. Thus, this study aims to obtain an insight into the effect of residents' behaviours on energy use. The research starts from the assumption that there are some differences in energy consumptions between households with different service life. To investigate the energy consumption in 20 households, the authors visited maintenance offices to obtain the metering data, and conducted in-depth interviews to investigate the residents' energy use behaviours in terms of heating, cooling, bathing, cooking, lighting, appliance and ventilation. Contrary to expectations, it was identified that the households in the 33-year-old apartments did not use more energy than those in the 11-year-old apartments. Rather, energy conservation behaviours have more effect on energy consumption, regardless of the service life of buildings.

14/02890 'Fracking' controversy and communication: using national survey data to understand public perceptions of hydraulic fracturing

Boudet, H. *et al. Energy Policy*, 2014, 65, 57–67.

The recent push to develop unconventional sources of oil and gas both in the USA and elsewhere using hydraulic fracturing ('fracking') has generated a great deal of controversy. Effectively engaging stakeholders and setting appropriate policies requires insights into current public perceptions of this issue. Using a nationally representative US sample ($N = 1061$), this study examines public perceptions of hydraulic fracturing including: 'top of mind' associations, familiarity with the issue, levels of support/opposition and predictors of such judgements. Similar to findings on other emerging technologies, the results suggest limited familiarity with the process and its potential impacts and considerable uncertainty about whether to support it. Multiple regression analysis ($r^2 = 0.49$) finds that women, those holding egalitarian world views, those who read newspapers more than once a week, those more familiar with hydraulic fracturing and those who associate the process with environmental impacts are more likely to oppose fracking. In contrast, people more likely to support fracking tend to be older, hold a bachelor's degree or higher, are politically conservative, watch television news more than once a week, and associate the process with positive economic or energy supply outcomes. Based on these findings, the authors discuss recommendations for future research, risk communication and energy policy.

14/02891 Households' heating investments: the effect of motives and attitudes on choice of equipment

Lillemo, S. C. *et al. Biomass and Bioenergy*, 2013, 57, 4–12.

This paper reports on an online survey conducted in Norway to investigate how attitudes, motives, residence characteristics and socioeconomic factors relate to households' investments in four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps. It was found find that perceptions about characteristics such as appearance, efficiency, cost, time and effort required to use the equipment, and environmental impact differ greatly between the four types of heating equipment. It was also found that 52% of the households invested more than €375 in heating equipment in the previous 10 years, and that 34% of those invested in at least two types of heating equipment. Finally, using discrete choice models, motive, environmental attitude, characteristics of the residence and demographic factors were found to affect households' heating investment likelihood and choice of heating equipment. For example, people whose main motive was to reduce costs were more likely to invest in heat pumps, whereas investors in pellet stoves were more concerned about the environment.

14/02892 Human factors issues in the management of emergency response at high hazard installations

Woodcock, B. and Au, Z. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (3), 547–557.

This paper seeks to explore the human factors issues involved in emergency responses at high hazard installations, in particular offshore installations. Human factors are an important consideration in the event of an emergency for several reasons. First, an emergency event is a highly safety critical situation and human errors may lead to severe consequences. Second, apart from fault detection and alarming, emergency response operations (e.g. decision making, response activities and safeguards to errors) consist primarily of human operations. Hence, there is an emphasis on operations being carried out correctly and at the appropriate time. Third, although the tasks involved are relatively simple, they are often carried out under extreme circumstances (e.g. high stress) and in a harsh or even hazardous physical environment. This paper will discuss the role of human factors in emergency response and look at the way in which study of human factors can help determine the physical design of means of escape as well as the design of response procedures and supporting equipment. The human factors study provides a suite of tools and techniques aimed at identifying the causes and consequences of human errors. These can be utilized to predict potential human behaviour within emergency response scenarios, such as emergency escape and evacuation on offshore installations. Conclusions gained from these assessments can be used to inform designs of installations and procedures in order to facilitate safe and timely escape from hazardous situations. This paper will explore how some of these techniques could be adopted to assess and optimize emergency response.

14/02893 Quantitative risk assessment of R290 in ice cream cabinets

Colbourne, D. and Espersen, L. *International Journal of Refrigeration*, 2013, 36, (4), 1208–1219.

This study addresses the flammability risk of hydrocarbon (HC) refrigerants within horizontal type ice-cream cabinets (ICC). Quantitative risk assessment (QRA) is used to estimate the likelihood of ignition of leaked refrigerant and severity of the consequences. Variables were evaluated including effect of room size, positioning of ICC, compressor compartment fan airflow and ignition source distribution. To strengthen the QRA, tests were carried out for refrigerant leakage and effects of ignition to validate dispersion and consequence models. Ignition frequency is between 1×10^{-8} and 2×10^{-13} per year. The maximum overpressure and thermal intensity within the room is 3 kPa and $200\,\mathrm{s}\,(\mathrm{kW\,m^{-2}})^{4/3}$, respectively and 6.5 kPa and $20\,\mathrm{s}\,(\mathrm{kW\,m^{-2}})^{4/3}$ from within the compressor compartment. The risks were found to be negligible compared to background and other reference values.

14/02894 Renewable Energy Sources Act and Trading of Emission Certificates: a national and a supranational tool direct energy turnover to renewable electricity-supply in Germany

Kirsten, S. *Energy Policy*, 2014, 64, 302–312.

After the nuclear disaster at Fukushima in 2011, Germany decided to phase out atomic energy and to not increase CO_2 emissions. This paper discusses the promotion systems that are used. The proportions of renewable energies in Germany's electricity consumption increased from 3% in 1990 to 23% in 2012. This development was introduced and guided by the Renewable Energy Sources Act. The law guarantees a privileged acceptance of electricity and a fixed gratification for 20 years to the operators of regenerative power plants. It allows the operators to install regenerative power plants at a reduced risk. In contrast, the international means for CO_2 reduction is the trading of emission certificates, which is also valid for Germany. The paper discusses how the promotion of the Renewable Energy Act and other plant-based promotion systems fit into this condition. It also elucidates the actual decline of promotion, its problems to the country's environmental economy and the approach of decentralized photovoltaic (PV) energy plants towards economic efficiency. Germany's energy turnaround to a regenerative energy supply is characterized by a strong and differentiated promotion system. Substantial efforts have to be made as the percentage of the renewable energy sources has significantly increased but is still under 25%.

14/02895 Residents' perceptions of wind turbines: an analysis of two townships in Michigan

Groth, T. M. and Vogt, C. *Energy Policy*, 2014, 65, 251–260.

Wind energy development has become a 'hot topic' across Michigan as this US state seeks to achieve 10% of energy delivered to consumers from renewable sources. The focus of this effort to generate renewable energy has centred around wind energy. Wind turbines have been constructed at numerous locations across the state. The lower peninsulas' eastern counties near Lake Huron and Saginaw Bay were designated by the wind energy resource zone board as one such area of strong sustained wind in the state. Turbines have been constructed in 'pockets' across this 'thumb' region, yet half a decade after the first turbines were constructed, negative perceptions are still attributed to wind turbines. This paper examines residents of wind farm locations as a whole and independently as groups (those in opposition and in support of development) to identify what, if any similarities and differences, exist between the residents' perceptions. Qualitative analysis on stated negative perceptions unveiled common issues with residents: increased price of electricity with wind energy, noise from the turbine rotation and uncertainty surrounding the long-term effects of wind turbines. These areas of concern seem to persist years after construction was completed.

14/02896 Response of magnetic properties to heavy metal pollution in dust from three industrial cities in China

Zhu, Z. *et al. Journal of Hazardous Materials*, 2013, 246–247, 189–198.

The magnetic method is a reliable and powerful technique to identify the relative contribution of industrial pollutants. However, it has not been fully applied in urban area affected by non-ferrous metal (NFM) smelting or processing activities. The aim of this study is to explore the applicability of magnetic methods for detecting heavy metal contamination in dust from three NFM smelting/processing industrial cities (Ezhou, Zhuzhou and Hezhang) in China. The enhancements of magnetic susceptibility and saturation isothermal remanent magnetization together with heavy metals were significant in the studied areas in comparison with the background values. Scanning electron microscope analysis revealed that magnetic particles in dust from Ezhou were dominated by spherules, while those from Zhuzhou and Hezhang were mainly consisted of irregular-shaped particles. κ–T curves and X-ray diffraction analyses indicated that the magnetic particles from Ezhou were dominated by magnetite and metallic iron, whereas those from Zhuzhou and Hezhang were consisted of magnetite and hematite. This study indicates that magnetic properties of the dust are sensitive to the NFM smelting/processing related heavy metal pollutants. However, the relationship between magnetic parameters and heavy metals was influenced by the presence of metallic iron particles and multi-sources of metal pollutants.

14/02897 Sensitivity analysis of the effect of occupant behaviour on the energy consumption of passive house dwellings

Blight, T. S. and Coley, D. A. *Energy and Buildings*, 2013, 66, 183–192.
There has been a history of low-energy design failing to translate into low measured energy consumption in domestic buildings. In part this failure can be attributed to occupant behaviour and household variation. It is therefore important to provide a method where such variations can be accounted for so that deviations from design values can be identified as natural variation rather than design failures. This paper addresses the likely range of occupant behaviours and the resultant impact on heating energy consumption for domestic Passivhaus buildings. Realistic, quasi-empirical, profiles for different occupancies, lighting, and appliance-use were applied to a set of 100 terraced Passivhaus units, and modelled in a dynamic building simulation program. Strong correlations between the results and measured data from a large set of similar properties are shown. Multiple regression techniques were used to identify the relationship between space heating load and behavioural variables. This led to the development of a regression equation which can be used to estimate the likely space-heating requirements of a household given particular behavioural variables, and to the test the impact of certain behaviours on annual heating energy demand. It is found that in general passive houses are less sensitive to behaviour than anticipated.

14/02898 Social availability of residual woody biomass from nonindustrial private woodland owners in Minnesota and Wisconsin

Becker, D. R. *et al. Biomass and Bioenergy*, 2013, 56, 82–91.
An important and potentially underused source of biomass that could be utilized in energy production is from non-industrial private woodlands. The authors employ the theory of planned behaviour to estimate the social availability of woody biomass as a function of landowner behaviour intent, landowner characteristics, forest land characteristics and biomass price on stated willingness to harvest biomass in conjunction with a commercial timber harvest. A mail survey was administered to 1109 non-industrial private woodland owners in a 26-county region in north-east Minnesota and north-west Wisconsin during the autumn of 2009. Using binary logistic regression, the authors found that the payment level offered to harvest biomass plays a significant role in landowners' decisions, but that non-monetary factors are also important. Landowner attitudes and opinions regarding soil impacts, aesthetics and energy independence were important predictors of stated willingness to harvest. Social norms were also significant as manifested through the influence of neighbours. These findings expand existing research and are useful for profiling non-industrial private woodland owners to identify sustainable sources of biomass to supply a burgeoning bioenergy sector in the US's Lake states.

14/02899 Techno-economic and social analysis of energy storage for commercial buildings

Yan, X. *et al. Energy Conversion and Management*, 2014, 78, 125–136.
Techno-economic and social evaluation methodologies for energy storage systems applied for commercial buildings are presented. The demand analysis methodology is used to determine power rating and capacity. The technical and economical evaluations are described to analyse the techno-economic feasibility by the financial indices: net present value, internal rate of return and initial investment payback period. Other benefits, including improved power quality/reliability, improved utilization of grid assets and reduced greenhouse gas and air pollutant emissions, are estimated in a social evaluation. Finally, an illustrative example combining the measured load data and the current economic parameters is analysed for three scenarios: 6.5 kW/12.7 kW h lead–acid battery, 5.4 kW/12.4kW h sodium–sulfur battery and 5.15 kW/10.4kW h lithium ion battery for the same peak shaving demand 4.9 kW and a 2-hour discharge. The results and discussion of these examples show that all three typical battery energy storage technologies are technically feasible, however, investment in sodium–sulfur and lithium ion batteries for energy storage in commercial buildings should be done with caution, as lead–acid battery systems are the more economic choice at the moment. However, systems with lithium ion batteries provide the maximum social benefits due to their high cycle efficiency. Lastly, the standard discount rate with the largest absolute value of sensitivity coefficient has the biggest influence on the net present value through the sensitivity analysis.

14/02900 The importance of social networks in the Norwegian firewood industry

Nybakk, E. *et al. Biomass and Bioenergy*, 2013, 57, 48–56.
This study examines the relationship between social network size, innovation and firm performance among firewood producers in Norway. Moreover, it investigates how this relationship is affected both by the structure and variations in networks and by firm size and age. A questionnaire-based survey was sent to managers of firms (including one-person firms) in the firewood industry in Norway. A total of 645 usable replies were received, and the theoretical model was tested using structural equation modelling. The findings show that social network size has a positive effect on firm performance via innovation by firewood producers. Furthermore, the results show that firewood producers with fewer involved family members and more variation in occupation and entrepreneurial experience in their networks benefit more from larger social networks than other producers do.

14/02901 The influence of energy audits on the energy efficiency investments of private owner-occupied households in the Netherlands

Murphy, L. *Energy Policy*, 2014, 65, 398–407.
Energy audits are promoted as an effective tool to drive investment in energy efficiency measures in the residential sector. Details of the impact of audits are mixed despite operating in many countries for several decades. The aim of research presented here is to explore the role of audits on investment in energy efficiency measures by private owner-occupied householders in the Netherlands. Results showed that the main influence of the energy audit was to confirm information held by householders. A significant portion of audit recommendations was ignored, the main reason being that householders considered their dwellings to be adequately energy efficient. A comparison of audit recipients to non-recipients showed that audit recipients did not adopt, plan to adopt or invest in more energy efficiency measures than non-recipients. In fact, non-recipients adopted more and invested more in measures. It is concluded that energy-based renovation is driven by householder perception of comfort and acceptable outlay on energy bills and not necessarily to expert technical tailored information on the potential to reduce CO_2 emissions and environmental impact. Results support arguments for minimum energy efficiency standards and performance-based incentives.

14/02902 The problems and solutions of predicting participation in energy efficiency programs

Davis, A. L. and Krishnamurti, T. *Applied Energy*, 2013, 111, 277–287.
This paper discusses volunteer bias in residential energy efficiency studies. The authors briefly evaluate the bias in existing studies and then show how volunteer bias can be corrected when not avoidable, using an on-line study of intentions to enrol in an in-home display trial as an example. It was found that the best predictor of intentions to enrol was expected benefit from the in-home display. Constraints on participation, such as time in the home and trust in scientists, were also associated with enrolment intentions. Using Breiman's classification tree algorithm, it was found that the best model of intentions to enrol contained only five variables: expected enjoyment of the programme, presence in the home during morning hours, trust (in friends and in scientists), and perceived ability to handle unexpected problems. These results suggest that a short questionnaire, that takes at most 1 min to complete, would allow better control of volunteer bias than a more extensive questionnaire. This paper should allow researchers who employ field studies involving human behaviour to be better equipped to address volunteer bias.

14/02903 The role of sea ports in end-to-end maritime transport chain emissions

Gibbs, D. *et al. Energy Policy*, 2014, 64, 337–348.
This paper's purpose is to investigate the role of sea ports in helping to mitigate the greenhouse gas emissions associated with the end-to-end maritime transport chain. The analysis is primarily focused on the UK, but is international in application. The paper is based on both the analysis of secondary data and information on actions taken by ports to reduce their emissions, with the latter data collected for the main UK ports using their published reports and/or by interviews. Only a small number of ports (representing 32% of UK port activity) actually measure and report their carbon emissions in the UK context. The emissions generated by ships calling at these ports are analysed using a method based on Department for Transport Maritime Statistics Data. In addition, a case example (Felixstowe) of emissions associated with lorry movements to and from ports is presented, and data on vessel emissions at berth are also considered. These analyses indicate that emissions generated by ships during their voyages between ports are of a far greater magnitude than those generated by the port activities. Thus, while reducing the ports' own emissions is worthwhile, the results suggest that ports might have more impact through focusing their efforts on reducing shipping emissions.

14/02904 Utilization of LPG and gasoline engine exhaust emissions by microalgae

Taştan, B. E. *et al. Journal of Hazardous Materials*, 2013, 246–247, 173–180.

The effect of engine exhaust emissions on air pollution is one of the greatest problems that the world is facing today. The study focused on the effects of realistic levels of engine exhaust emissions of liquid petroleum gas (LPG) and gasoline (GSN) on *Phormidium* sp. and *Chlorella* sp. Multi-parameters including pH, different medial compositions, fuel types, flow rates and biomass concentrations were described in detail. Effects of some growth factors such as triacontanol (TRIA) and salicylic acid (SA) have also been tested. The maximum biomass concentration of *Phormidium* sp. reached after 15 days at 0.36 and 0.15 g/L initial biomass concentrations were found as 1.160 g/L for LPG emission treated cultures and 1.331 g/L for GSN emission treated cultures, respectively. The corresponding figures were 1.478 g/L for LPG emission treated cultures and 1.636 g/L for GSN emission treated cultures at 0.65 and 0.36 g/L initial *Chlorella* sp. biomass concentrations. This study highlights the significance of using *Phormidium* sp. and *Chlorella* sp. for utilization of LPG and GSN engine exhaust emissions by the help of growth factors.

CO_2, NO_x, SO_2 and particulate emissions

14/02905 A small-sample hybrid model for forecasting energy-related CO_2 emissions

Meng, M. *et al. Energy*, 2014, 64, 673–677.

Mitigating the impact of developing countries to global climate change has become an important issue in the fields of science and politics. This study proposes a small-sample hybrid model for forecasting the energy-related CO_2 emissions of developing countries. The CO_2 emissions of these countries have not reached the inflection point of the long-term *S*-shaped curve and usually present short-term linear or approximately exponential trends. This concern is considered in the design of a hybrid forecasting equation combined by a non-homogeneous exponential equation and a linear equation. The estimated parameters of the hybrid equation are obtained by minimizing the residual sum of squares and solving for a non-constrained optimization equation. To evaluate the performance of the hybrid model, the traditional linear model, the grey model, and the hybrid model are used to forecast the CO_2 emissions of China from 1992 to 2011. Analysis of forecasting results shows that the hybrid model can respond more quickly to changes in emission trends than can the two models because of the specialized equation structure. Overall error analysis indicators also show that hybrid model often obtains more precise forecasting results than do the other two models.

14/02906 Approaches to greenhouse gas accounting methods for biomass carbon

Downie, A. *et al. Biomass and Bioenergy*, 2014, 60, 18–31.

This investigation examines different approaches for the greenhouse gas (GHG) flux accounting of activities within a tight boundary of biomass carbon cycling, with scope limited to exclude all other aspects of the lifecycle. Alternative approaches are examined that (a) account for all emissions including biogenic CO_2 cycling – the biogenic method; (b) account for the quantity of carbon that is moved to and maintained in the non-atmospheric pool – the stock method; and (c) assume that the net balance of carbon taken up by biomass is neutral over the short-term and hence there is no requirement to include this carbon in the calculation – the simplified method. This investigation demonstrates the inaccuracies in both emissions forecasting and abatement calculations that result from the use of the simplified method, which is commonly accepted for use. It has been found that the stock method is the most accurate and appropriate approach for use in calculating GHG inventories, however short-comings of this approach emerge when applied to abatement projects, as it does not account for the increase in biogenic CO_2 emissions that are generated when non-CO_2 GHG emissions in the business-as-usual case are offset. Therefore the biogenic method or a modified version of the stock method should be used to accurately estimate GHG emissions abatement achieved by a project. This investigation uses both the derivation of methodology equations from first principles and worked examples to explore the fundamental differences in the alternative approaches. Examples are developed for three project scenarios including; landfill, combustion and slow-pyrolysis (biochar) of biomass.

14/02907 Carbon dioxide emission while heating in selected European countries

Gajewski, A. *et al. Energy and Buildings*, 2013, 65, 197–204.

Carbon dioxide emissions resulting from the use of heat pumps are estimated for 100 years in selected European countries. These emissions were calculated including the source of the electrical energy. The highest emissions are in Macedonia and Poland, where coal and lignite are the major sources of electrical energy. The lowest emissions are in Norway, where the major portion of the electricity is produced from renewable resources. The highest emissions are 40 times higher than the lowest emissions, so the heat pump can be a ‘green’ heat source only in those countries where electrical energy is produced from hydropower or nuclear power plants. The methodology to calculate the critical value of the average generation factor for power plants, from which the heat pump causes lower carbon dioxide emissions, was developed. As an example, the calculations were performed for the ground heat pump, gas condensing boiler and the oil boiler. In conclusion, for the countries where solid fuel is major source of electricity, heat pumps should not be applied but instead condensing gas boilers should be used.

14/02908 Condensation heat transfer characteristics of CO_2 in a horizontal smooth tube

Kang, P. *et al. International Journal of Refrigeration*, 2013, 36, (3), 1090–1097.

The condensation heat transfer characteristics of CO_2 flowing in a horizontal smooth tube were investigated. The tube diameter was 5.15 mm. The condensation temperature ranged from -10 to 5 °C, and the mass flux was from 600 to 1000 $kg\,m^{-2}\,s^{-1}$. When the temperature changed from 0 to -10 °C, the increase rate of the heat transfer coefficient was from 9.4 to 14.6%, and the pressure drop increased from 6.2 to 52.9%. When the mass flux increased from 600 to 1000 $kg\,m^{-2}\,s^{-1}$, the heat transfer coefficient increased from 6 to 35%, and the pressure drop increased from 60 to 165%, which were dependent on the condensation temperature. The increases come from the change of vapour velocity and thermophysical properties with condensation temperature. Considering large variation of mass flux from 200 to 1200 $kg\,m^{-2}\,s^{-1}$ by including the existing studies, the effect of mass flux on condensation heat transfer coefficient was minor.

14/02909 CO_2 transport strategy and its cost estimation for the offshore CCS in Korea

Jung, J.-Y. *et al. Applied Energy*, 2013, 111, 1054–1060.

The Republic of Korea is the ninth largest CO_2 emission country in 2009 according to the International Energy Agency (IEA). To mitigate the effects of CO_2 on the climate, Korea should reduce its anthropogenic CO_2 emissions from sources such as power plants and iron works. CO_2 capture and storage (CCS) technology is regarded as one of the most promising carbon reduction options. The demonstration project of CCS is funded by the Korean government to demonstrate the capture, transportation and storage of 1 M CO_2 per year in Korea by 2020. This study established the CO_2 transport strategies from the sources to sinks for the CCS demonstration in Korea. Also the cost estimations were carried out with the CO_2 transport strategies. The CO_2 transport methods suggested in this study are the pipelines for both onshore and offshore, and a ship-based concept consisting of a pipeline from the source to coastal terminal (including the liquefaction facility on a barge) and a CO_2 carrier from the terminal to sink (including the temporary storage near offshore sink). Although the present study is now on-going to optimize the CO_2 transport infrastructure for the offshore CCS in Korea, the preliminary results show the CO_2 transport cost for the pipeline system is lower than that for the shipping in the present status. The result is meaningful only for the specific source and storage sites studied in this study.

14/02910 Dissolution kinetics of magnesium hydroxide for CO_2 separation from coal-fired power plants

Bharadwaj, H. K. *et al. Journal of Hazardous Materials*, 2013, 250–251, 292–297.

The dissolution of magnesium hydroxide in water for the release of magnesium and hydroxyl ions into the solution to maintain suitable alkalinity is a crucial step in the $Mg(OH)_2$-based CO_2 absorption process. In this study, the rate of dissolution of $Mg(OH)_2$ was investigated under different operating conditions using a pH stat apparatus. The dissolution process was modelled using a shrinking core model and the overall $Mg(OH)_2$ dissolution process was found to be controlled by the surface chemical reaction of $Mg(OH)_2$ with H^+ ions. Under the chemical reaction control regime, the dissolution of $Mg(OH)_2$ in alkaline conditions was found not to follow a first-order reaction, and the fractional order of reaction was estimated to lie between 0.20 and 0.31. This suggests that the dissolution reaction is a non-elementary reaction, consisting of a sequence of elementary reactions, via most likely forming a surface magnesium complex. The true activation energy value of 76 ± 11 kJ/gmol was found to be almost twice as much as the observed activation energy value of 42 ± 6 kJ/gmol determined at pH 8.6, and was comparable with the previously reported values. The particle sizes predicted from the intrinsic kinetics determined from the model were in good agreement with the experimentally measured particle sizes during the dissolution process.

14/02911 Effect of kaolin additive on $PM_{2.5}$ reduction during pulverized coal combustion: importance of sodium and its occurrence in coal

Si, J. *et al. Applied Energy*, 2014, 114, 434–444.

Little work has been performed on the importance of sodium and its occurrence in coal to $PM_{2.5}$ (particles less than 2.5 μm in aerodynamic diameter) reduction by kaolin during O_2/N_2 combustion and O_2/CO_2 combustion at high temperatures. In this study, the combustion experiment of a treated low-sodium coal with sodium aluminosilicate additive was conducted in a laboratory-scale drop tube furnace at 1500 °C to reveal the contribution of mineral melting and coalescence to $PM_{2.5}$ reduction. Meanwhile, two typical Na-loaded coals (in which the sodium was loaded in the form of NaCl and sodium carboxylate, respectively) with kaolin added were also burnt under O_2/N_2 and O_2/CO_2 atmospheres to investigate the effect of interaction between kaolin and different chemical form sodium on $PM_{2.5}$ reduction. The results show that sodium aluminosilicate is able to promote the migration of $PM_{0.5–2.5}$ (particles in aerodynamic diameter of 0.5–2.5 μm) to form coarse particles. Due to the stronger reactivity of sodium carboxylate reacting with kaolin than that of NaCl, $PM_{0.2–0.5}$ (particles in aerodynamic diameter of 0.2–0.5 μm) decreases more significantly in the combustion when adding kaolin into the NaAc-loaded coal than into NaCl-loaded coal. In addition, the PM0.2–0.5 reduction in O_2/CO_2 combustion is lower than that in O_2/N2 combustion owing to the less vaporization of metals and the slower diffusion rate of vapours in the O_2/CO_2 atmosphere in comparison to those in the O_2/N2 atmosphere. The mineral coalescence varied in interactions of kaolin with NaAc and NaCl. Besides, the $PM_{0.5–2.5}$ emission differed as a result of differences in coal characteristics and the atmosphere, and this would cause the difference of collision frequency between particles and additive. With the joint actions of mineral coalescence and particle collision, the NaAc-loaded coal has a higher $PM_{0.5–2.5}$ reduction by kaolin than NaCl-loaded coal, especially under the O_2/N_2 combustion. An expression describing the relationship of $PM_{0.5–2.5}$ reduction, mineral coalescence and particle collision was fitted and it is found that the mineral coalescence has a stronger influence than particle collision on $PM_{0.5–2.5}$ reduction by kaolin.

14/02912 Experimental study of hexagonal and square diesel particulate filters under controlled and uncontrolled catalyzed regeneration

Tsuneyoshi, K. and Yamamoto, K. *Energy*, 2013, 60, 325–332.

Although diesel engines have high thermal efficiency, large amounts of particulate matter including soot are emitted. A wall-flow diesel particulate filter (DPF) is one of the most important technologies for diesel emission control. However, the soot accumulation inside the DPF causes an increase of pressure loss. Then, the accumulated diesel soot needs to be burned, which is called a filter regeneration process. This study investigated the soot combustion on bare and catalysed DPFs under controlled and uncontrolled regeneration. Two types of DPFs with conventional square and hexagonal cells were used. Results show that, in comparison with the bare DPF, the regeneration efficiency of the catalysed DPF is clearly higher, indicating a marked effect of catalysts. Independent of regeneration temperature, a greater increase in the regeneration efficiency of the catalysed DPF was confirmed under controlled regeneration. On the other hand, under uncontrolled regeneration, the maximum temperature of the catalysed DPF is higher than that of the bare DPF, and it is reached shorter times. Interestingly, by comparing the conventional square cell DPF, the soot oxidation of the hexagonal cell DPF is promoted under controlled and uncontrolled regeneration.

14/02913 Identification of management strategies for CO_2 capture and sequestration under uncertainty through inexact modeling

Zhang, X. *et al. Applied Energy*, 2014, 113, 310–317.

Geologic sequestration has been considered as an effective and critical means for significant reductions of CO_2 amounts to the atmosphere among various mitigation approaches. A carbon capture and storage (CCS) management system must be a complex system to accommodate the relevant social, economic, environmental and political factors. Effective management of such a complex system involves balancing trade-offs among these key influencing factors. In addition, carbon-emission trading is increased attention as a mechanism for addressing emissions quota shortage problems. Emissions markets have potentials to mediate between various emission sources and CO_2 capture and sequestration projects in a systematic manner. The objective of this study was to develop an inexact management model (ICSM) to identify optimal strategies for planning CO_2 capture and sequestration with a CCS system involving multiple emission sources, multiple capture technologies and multiple project periods. Two mechanisms are considered including with and without carbon emissions trading. The proposed model is based on the interval programming method, where uncertain information is directly incorporated and communicated into the optimization processes through the use of interval numbers. The ICSM model has been applied to a hypothetical case study in CCS management to demonstrate its applicability. The results indicated that total system costs under a trading mechanism would be less than those under a non-trading mechanism through more effective re-allocation of emission quota to different sources within the entire CCS system. The obtained solutions could provide more flexibility for the decision makers in generating appropriate management practices for carbon capture and sequestration.

14/02914 NO emission characteristics of superfine pulverized coal combustion in the O_2/CO_2 atmosphere

Liu, J. *et al. Energy Conversion and Management*, 2014, 77, 349–355.

The combination of O_2/CO_2 combustion and superfine pulverized coal combustion technology can make full use of their respective merits, and solve certain inherent disadvantages of each technology. The technology of superfine pulverized coal combustion in the O_2/CO_2 atmosphere is easy and feasible to be retrofitted with few reconstructions on the existing devices. It will become a useful and promising method in the future. In this paper, a one-dimensional drop-tube furnace system was adopted to study the NO emission characteristics of superfine pulverized coal combustion in the O_2/CO_2 atmosphere. The effects of coal particle size, coal quality, furnace temperature, stoichiometric ratio, etc. were analysed. It is important to note that coal particle sizes have significant influence on NO emissions in the O_2/CO_2 combustion. For the homogeneous NO reduction, smaller coal particles can inhibit the homogeneous NO formations under fuel-rich combustion conditions, while it becomes disadvantageous for fuel-lean combustion. However, under any conditions, heterogeneous reduction is always more significant for smaller coal particle sizes, which have smoother pore surfaces and simpler pore structures. The results from this fundamental research will provide technical support for better understanding and developing this new combustion process.

14/02915 Non-separable pollution control: implications for a CO_2 emissions cap and trade system

Agee, M. D. *et al. Resource and Energy Economics*, 2014, 36, (1), 64–82.

The federal government now faces considerable political pressure to add CO_2 to the existing set of criteria air pollutants. As with current criteria pollutants, proposals call for control of CO_2, assuming that the control of each of the three criteria pollutants is separable from the others. However, control of CO_2, SO_2, and NO_x emissions is most appropriately viewed as joint rather than separable based on engineering relationships. Empirically, the authors also found considerable jointness. Using a 10-year panel for 77 US electric utilities, which comprise the largest sector in terms of energy-related CO_2 emissions, the authors estimated a multiple-input, multiple-output directional distance function combining good inputs (production capital, pollution control capital, labour, and energy) and a bad input (sulfur burned) to produce good outputs (residential and industrial/commercial electricity production) and bad outputs (SO_2, NO_x, and CO_2). They found that while utilities do not directly control CO_2 emissions, considerable jointness exists across SO_2, NO_x, and CO_2 emissions. Failure to account for this jointness increases the cost of pollution control, making it less acceptable to the public and policymakers. The authors also computed the technical efficiency of the set of utilities and find that considerable cost savings could be achieved by adopting the best technology for production of electricity and reduction of pollutants.

14/02916 Performance study of a transcritical carbon dioxide cycle with an expressor

Sun, Z. *et al. Energy*, 2013, 60, 77–86.

This paper provides an energy efficiency study of transcritical carbon dioxide systems by comparing six cycles with and without an expressor (expander–compressor), which serves as an assistant compressor or the main compressor. Several different expander–compressor arrangements in the system are investigated. The mass flow rate and compression ratio of the expander–compressor are affected by these arrangements. The coefficient of performance (COP) of series model of two-stage compression transcritical CO_2 cycle (STM) with an expressor as the main compressor) is found to be the highest. Although the intermediate pressure between the two compressor stages in series model of two-stage compression transcritical CO_2 cycle (STS) with an expressor as an assistant compressor in the second stage) cannot approach the optimum value, its COP approaches that of STM at a high evaporation temperature. Parallel model of single-stage compression CO_2 transcritical cycle with an expressor) and parallel model of single-stage compression CO_2 transcritical cycle with an expressor and gas–liquid separator) may be feasible options for reducing the dimensions of a compressor. The expander and compressor efficiencies were found to be very important factors for the utilization of an expressor.

14/02917 Targeting for carbon sequestration retrofit planning in the power generation sector for multi-period problems

Ooi, R. E. H. *et al. Applied Energy*, 2014, 113, 477–487.

Carbon constrained energy planning (CCEP) is useful to ensure that the CO_2 emissions limit for a region is met through deployment of low-carbon technologies. The increased demand in energy consumption due to economic growth requires additional energy supply and generation which would subsequently increase the carbon emissions. Nevertheless, most countries are now committed to reduce carbon emission to achieve long-term sustainability goals. However, the development of alternative energy sources or carbon capture and storage (CCS) initiatives for power plants entails major capital investments. This paper demonstrates how these issues may be handled using CCEP with insight- and optimization-based targeting techniques for multi-period scenarios. Both approaches were developed recently for CCEP problems, but previous techniques were limited to single-period planning. The extensions to multi-period scenarios are demonstrated in this work with hypothetical illustrative examples, as well as a Malaysian case study.

14/02918 The reduction of greenhouse gas emissions from freight transport by pooling supply chains

Pan, S. *et al. International Journal of Production Economics*, 2013, 143, (1), 86–94.

It is well known that freight consolidation is an effective way to improve the utilization of logistics resources. In fact today, this policy is locally and fragmentally implemented at the operational level. This study explored the environmental impact of pooling of supply chains at the strategic level (merging supply chains). With real data from two main French retail chains and through an optimization model, the CO_2 emissions were computed for two transport modes, road and rail. As regards the general dependency of the emissions produced by the modes of transport on their loads, the emissions functions of the two modes were both piecewise linear and discontinuous functions. The supply network pooling proposed here was an efficient approach in reducing CO_2 emissions. While the attention of this study was focused on the emissions, transportation costs were also studied and analysed.

14/02919 Towards ideal NO_x control technology for bio-oils and a gas multi-fuel boiler system using a plasma-chemical hybrid process

Fujishima, H. *et al. Applied Energy*, 2013, 111, 394–400.

A super-clean boiler system comprising a multi-fuel boiler and a reactor for plasma-chemical hybrid NO_x after-treatment is developed and its industrial applications are examined. The purpose of this research is to optimally reduce NO_x emissions and use waste bio-oil as a renewable energy source. First, NO oxidation using indirect plasma at elevated flue gas temperatures is investigated. It is clarified that more than 98% of NO is oxidized when the temperature of the flue gas is less than 130 °C. Three types of waste bio-oils (waste vegetable oil, rice bran oil and fish oil) are burned in the boiler as fuels with a rotary-type burner for CO_2 reduction considering carbon neutrality. NO_x in the flue gases of these bio-oils is effectively reduced by the indirect plasma-chemical hybrid treatment. Ultralow NO_x emission of <2 ppm is achieved for 450 min in the firing of city natural gas fuel. The boiler system can be successfully operated automatically according to unsteady steam demand and using an empirical equation for Na_2SO_3 supply rate, and can be used in industries as an ideal NO_x control technology.

Hydrocarbon emissions

14/02920 Comparative assessment of bioremediation approaches to highly recalcitrant PAH degradation in a real industrial polluted soil

Lladó, S. *et al. Journal of Hazardous Materials*, 2013, 248–249, 407–414.

High recalcitrant characteristics and low bioavailability rates due to aging processes can hinder high-molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs) bioremediation in real industrial polluted soils. With the aim of reducing the residual fraction of total petroleum hydrocarbons (TPH) and HMW-PAHs in creosote-contaminated soil remaining after a 180-day treatment in a pilot-scale biopile, either biostimulation (BS) of indigenous microbial populations with a lignocellulosic substrate (LS) or fungal bioaugmentation with two strains of white-rot fungi (WRF) (i.e. *Trametes versicolor* and *Lentinus tigrinus*) were comparatively tested. The impact of bivalent manganese ions and two mobilizing agents (MAs) (i.e. soybean oil and Brij 30) on the degradation performances of biostimulated and bioaugmented microcosms was also compared. The results reveal soil colonization by both WRF strains was clearly hampered by an active native soil microbiota. In fact, a proper enhancement of native microbiota by means of LS amendment promoted the highest biodegradation of HMW-PAHs, even of those with five aromatic rings after 60 days of treatment, but HMW-PAH-degrading bacteria were specifically inhibited when non-ionic surfactant Brij 30 was amended. Effects of bioaugmentation and other additives such as non-ionic surfactants on the degrading capability of autochthonous soil microbiota should be evaluated in polluted soils before scaling up the remediation process at field scale.

14/02921 Contribution of wood combustion to PAH and PCDD/F concentrations in two urban sites in northern Italy

Piazzalunga, A. *et al. Journal of Aerosol Science*, 2013, 56, 30–40.

The use of residential wood combustion represents an important renewable energy source, but it contributes in a considerable way to atmospheric particulate matter (PM) concentration in urban as well as in rural sites. Moreover, recent studies pointed out wood burning as an important source of polycyclic aromatic hydrocarbons (PAH). In the present work, the influence of wood combustion on PM was studied, investigating its contribution to the carbonaceous PM fraction and to benzo(a)pyrene (B[a]P) and polychlorodibenzo-p-dioxins and polychlorodibenzofurans (PCDD/F) concentrations, using levoglucosan as a marker. PM10 samples were collected daily for 6 months in two sites located in Piemonte (northern Italy): Torino and Susa. Composite monthly samples were chemically characterized, analysing the concentrations of levoglucosan, B[a]P, PCDD/Fs, organic carbon (OC), elemental carbon, major anions and cations, and metals. PM and OC concentrations were almost twice in Torino with respect to Susa, while levoglucosan and B[a]P concentrations were almost comparable at the two sites. Therefore, wood combustion affects more Susa than Torino. Concentrations of B[a]P and levoglucosan were highly correlated in both sites. Using the macro-tracer method and the emission factors reported in literature, the wood combustion percentage contribution to B[a]P concentration was estimated and resulted as the main source in both sites. The levoglucosan to soluble potassium ratio was higher in Torino with respect to Susa, indicating that combustion plants with different efficiency are used at the two sites. PCDD/F concentrations were higher in Torino than in Susa.

14/02922 Low temperature PAH formation in diesel combustion

Lea-Langton, A. R. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 119–125.

A study has been made of the formation of polyaromatic hydrocarbons (PAH) from biodiesel and conventional diesel fuel using a flow cell reactor at temperatures of 600–900 °C. The reaction mechanism has been validated by modelling studies using Chemkin. Pyrolysis of 9-[^{13}C]methylphenanthrene was undertaken to investigate the demethylation reaction of methyl-PAH compounds present in the original petroleum diesel. The product profiles obtained are shown to be similar for all fuels studied, pointing to a commonality of mechanism after the decomposition of the parent hydrocarbon. Dealkylation was demonstrated as the main reaction using the 9-[^{13}C]methylphenanthrene, however other [^{13}C] labelled species were also formed.

14/02923 Polycyclic aromatic hydrocarbons (PAH), soot and light gases formed in the pyrolysis of acetylene at different temperatures: effect of fuel concentration

Sánchez, N. E. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 126–133.

The effect of different inlet hydrocarbon concentrations (10,000, 20,000 and 30,000 ppmv) and reaction temperatures (873–1323 K) on polyaromatic hydrocarbons (PAH) and soot formation from acetylene pyrolysis has been studied. Sixteen PAH considered by the US Environmental Protection Agency as priority pollutants, together with light gases present at the outlet gas stream, have been quantified. Soot formed was collected on a filter at the reactor outlet. PAH found in the different phases (at the gas phase, adsorbed on soot, and/or stuck on reactor walls) were analysed by means of gas chromatography–mass spectrometry. Increasing fuel concentration and reaction temperature resulted in the increase in soot production together with decrease in the light gases at the reactor outlet. The acetylene conversion and the hydrogen concentration increased with the temperature, whereas benzene and the total PAH quantified showed a maximum around 1123 and 1223 K, respectively. In all cases, the concentration of products such as hydrogen, benzene, PAH and soot at the reactor outlet and the acetylene conversion increased with the reactant concentration. The temperature, at which the benzene showed a maximum concentration, was similar to the temperature where soot and PAH started to be formed. This suggests that benzene consumption leads to form PAH, which subsequently form soot, by following the well-known hydrogen abstraction/acetylene addition mechanism.

14/02924 Source attributions of hazardous aromatic hydrocarbons in urban, suburban and rural areas in the Pearl River Delta (PRD) region

Zhang, Y. *et al. Journal of Hazardous Materials*, 2013, 250–251, 403–411.

Aromatic hydrocarbons (AHs) are both hazardous air pollutants and important precursors to ozone and secondary organic aerosols. This study investigated 14 C_6–C_9 AHs at one urban, one suburban and two rural sites in the Pearl River Delta region during November–December 2009. The ratios of individual aromatics to acetylene were compared among these contrasting sites to indicate their difference in source contributions from solvent use and vehicle emissions. Ratios of toluene to benzene (T/B) in urban (1.8) and suburban (1.6) were near that of vehicle emissions. Higher T/B of 2.5 at the rural site downwind the industry zones reflected substantial contribution of solvent use while T/B of 0.8 at the upwind rural site reflected the impact of biomass burning. Source apportionment by positive matrix factorization revealed that solvent use, vehicle exhaust and biomass burning altogether accounted for 89–94% of observed AHs. Vehicle exhaust was the major source for benzene with a share of 43–70% and biomass burning in particular contributed 30% to benzene in the upwind rural site; toluene, C_8-aromatics and C_9-aromatics, however, were mainly from solvent use, with contribution percentages of 47–59%, 52–59% and 41–64%, respectively.

Life cycle analysis

14/02925 A methodological proposal for life cycle inventory of fertilization in energy crops: the case of Argentinean soybean and Spanish rapeseed

Fernández-Tirado, F. *et al. Biomass and Bioenergy*, 2013, 58, 104–116.

Fertilization is one of the agronomic practices that generates the highest environmental burdens in energy crops. However, this practice is essential, since its omission could entail long term processes of soil degradation, endangering the environmental sustainability of agricultural systems. In most of the life cycle assessments (LCAs) of energy crops found in the scientific literature, the inputs and outputs of nutrients are not calculated and the environmental impacts of nutrient loss are ignored as well. In this paper, a methodological approach to calculate the balance of nutrients that occurs during annual crop production in the context of the life cycle inventory phase of LCA is proposed and applied to two study cases of energy crops: rapeseed (*Brassica napus*) in Cádiz, Spain, and soybean (*Glycine max*) in Buenos Aires, Argentina. The results show that when rational fertilization is carried out, rapeseed fertilization in Spain generates more severe environmental impacts than soybean in the Argentinean Pampas when 1 ha of crop per year is used as the functional unit.

14/02926 A systematic review of bioenergy life cycle assessments

Muench, S. and Guenther, E. *Applied Energy*, 2013, 112, 257–273.

On a global scale, bioenergy is highly relevant to renewable energy options. Unlike fossil fuels, bioenergy can be carbon neutral and plays an important role in the reduction of greenhouse gas emissions. Biomass electricity and heat contribute 90% of total final biomass energy consumption, and many reviews of biofuel life cycle assessments (LCAs) have been published. However, only a small number of these reviews are concerned with electricity and heat generation from biomass, and these reviews focus on only a few impact categories. No review of biomass electricity and heat LCAs included a detailed quantitative assessment. The failure to consider heat generation, the insufficient consideration of impact categories, and the missing quantitative overview in bioenergy LCA reviews constitute research gaps. The primary goal of the present review was to give an overview of the environmental impact of biomass electricity and heat. A systematic review was chosen as the research method to achieve a comprehensive and minimally biased overview of biomass electricity and heat LCAs. The authors conducted a quantitative analysis of the environmental impact of biomass electricity and heat. There is a significant variability in results of biomass electricity and heat LCAs. Assumptions regarding the bioenergy system and methodological choices are likely reasons for extreme values. The secondary goal of this review was to discuss influencing methodological choices. No general consensus has been reached regarding the optimal functional unit, the ideal allocation of environmental impact between co-products, the definition of the system boundary, or how to model the carbon cycle of biomass. It was concluded that a higher level of transparency and a harmonization of the preparation of biomass electricity and heat LCAs are needed to improve the comparability of such evaluations.

14/02927 Assessing the lifecycle greenhouse gas emissions from solar PV and wind energy: a critical meta-survey

Nugent, D. and Sovacool, B. K. *Energy Policy*, 2014, 65, 229–244.

This paper critically screens 153 lifecycle studies covering a broad range of wind and solar photovoltaic (PV) electricity generation technologies to identify 41 of the most relevant, recent, rigorous, original, and complete assessments so that the dynamics of their greenhouse gas (GHG) emission profiles can be determined. When viewed in a holistic manner, including initial materials extraction, manufacturing, use and disposal/decommissioning, these 41 studies show that both wind and solar systems are directly tied to and responsible for GHG emissions. They are thus not actually emissions-free technologies. Moreover, by spotlighting the lifecycle stages and physical characteristics of these technologies that are most responsible for emissions, improvements can be made to lower their carbon footprint. As such, through in-depth examination of the results of these studies and the variations therein, this article uncovers best practices in wind and solar design and deployment that can better inform climate change mitigation efforts in the electricity sector.

14/02928 Combining life cycle costing and life cycle assessment for an analysis of a new residential district energy system design

Ristimäki, M. *et al. Energy*, 2013, 63, 168–179.

The focus of this study is on the life cycle design of a district energy system for a new residential development in Finland. This study analyses life cycle costs (LCC) and carbon emissions (life cycle assessment, LCA), i.e. the 'viability' of different energy systems through a methodological life cycle framework. By combining LCC and LCA, a life cycle management (LCM) perspective is portrayed to support decision-making on a long-term basis. The comparable energy design options analysed are: (1) district heating (reference design), (2) district heating with building integrated photovoltaic panels, (3) ground source heat pump and (4) ground source heat pump with building-integrated photovoltaic panels. The results show that the design option with the highest initial investment (4) is in fact the most viable from a life cycle perspective. This study further strengthens the connection between cost savings and carbon emissions reduction in a life cycle context. Thus, by implementing LCC and LCA analysis in an early design phase, justified economic and environmental design decisions can be identified to develop more sustainable urban areas.

14/02929 Comparative life cycle assessment of passive and traditional residential buildings' use with a special focus on energy-related aspects

Lewandowska, A. *et al. Energy and Buildings*, 2013, 67, 635–646.

This project carried out a life-cycle assessment (LCA) of four detached, single-family dwellings with a particular emphasis on the use stage. The LCA involved various types of activity within 100 years of use and related to operation (energy and water consumption), replacements and repairs, renovations and maintenance, land occupation, waste transport and waste management. Two of the four analysed buildings met passive house standards and their energy demands in the use stage were several times lower than those of their conventional counterparts. The aim of the research was to demonstrate whether lower nominal energy consumption is sufficient to get the best results of the environmental impact of passive buildings, or whether a type of energy used to cover the demand also plays an important role.

14/02930 Effects of land-use change on the carbon balance of 1st generation biofuels: an analysis for the European Union combining spatial modeling and LCA

Humpenöder, F. *et al. Biomass and Bioenergy*, 2013, 56, 166–178.

Biofuels are considered as an important option for the mitigation of climate change. However, the negative impact of land-use change (LUC) on soil and vegetation carbon pools may jeopardize the potentially achievable savings of greenhouse gas (GHG) emissions. In this study the impact of GHG emissions from LUC on the overall GHG performance of first-generation biofuels was analysed for the European Union (EU). The scenario-based analysis was done by coupling a spatial land-use model to a life cycle assessment (LCA) of biofuels. The biofuel demand in the scenarios was derived from figures for the transport sector of the EU's 27 member states. The calculation of GHG emissions was performed with a geographic information system. Finally, these results were integrated into the LCA approach of the EU Renewable Energy Directive (RED). Without taking LUC into account, the average GHG emission saving compared to fossil fuel use amounts to ~50%. In this case the mandatory 35% emission saving target laid down in the RED would be fulfilled. If LUC is considered, this target is reached under none of the simulated biofuel scenarios. In the most realistic scenario the GHG emission savings from first-generation biofuel use compared to fossil fuel use range between −2% and 13%. Based on the findings, it is concluded that national policy plans for biofuel use should be reconsidered and revised as in their current form they do not provide an adequate measure for the mitigation of climate change on an EU level.

14/02931 Energy–environment–economy assessment of waste management systems from a life cycle perspective: model development and case study

Dong, J. *et al. Applied Energy*, 2014, 114, 400–408.

How to choose an energy-efficient, environmentally friendly and economically affordable municipal solid waste (MSW) management system has been a major challenge to be taken up by decision makers. Although life cycle assessment (LCA) has been widely used for the evaluation of energy consumption and environmental burden, the economic factor is not considered yet in LCA procedures. Thus, in the present study, life cycle 2E (energy and environment) assessment is extended to a 3E (energy, environment and economy) model. To evaluate economic performance, life cycle cost (LCC) is adjusted in accordance with LCA. Afterwards, a multi-criteria decision-making method is improved to integrate 3E factors. A two-step weight factor analysis is also added, not only to test the robustness of the model, but also to adopt different preferences proposed by different stakeholder groups. This novel 3E model is then applied for the comparison of different MSW treatment technologies: (1) landfill, (2) landfill with biogas conversion to electricity and (3) incineration with energy recovery. Results show that incineration scores 0.944/1 and performs best among all scenarios; landfill with biogas to electricity, with final score 0.722/1, ranks second; and landfill without energy recovery (score: 0/1) is the worst choice. Furthermore, the weight factor analysis also shows a highly credibility of the results: when changing each factor's weight from 0 to 1, less than 30% of the cases exhibit the variation in ranking order; almost no change in ranking order occurs when considering the different perspectives from government, enterprise and residents.

14/02932 Environmental life-cycle assessment of rapeseed-based biodiesel: alternative cultivation systems and locations

Malça, J. *et al. Applied Energy*, 2014, 114, 837–844.

This article presents an assessment of the environmental performance of rapeseed-based biodiesel, addressing alternative geographical locations and cultivation systems for rapeseed (in Spain, France, Germany and Canada). Four environmental impact categories have been assessed using the CML 2001 life-cycle impact assessment method: abiotic depletion, global warming, acidification and eutrophication. Results show that rapeseed cultivation has the highest contribution to all the environmental impact categories evaluated, with a share between 40% (abiotic depletion, Germany) and 98% (eutrophication, Spain). The use of fertilizers and associated soil emissions are the main contributions to the environmental impacts of cultivation. Soil carbon changes due to different agricultural practices are particularly important in terms of the global warming impact of rapeseed-based biodiesel. The use of fossil methanol in biodiesel production has significant impacts in terms of abiotic depletion and the consumption of heavy fuel oil in transoceanic transportation is an important contributor to acidification.

14/02933 Incorporating life cycle external cost in optimization of the electricity generation mix

Rentizelas, A. and Georgakellos, D. *Energy Policy*, 2014, 65, 134–149.

The present work aims to examine the strategic decision of future electricity generation mix considering, together with all other factors, the effect of the external cost associated with the available power generation technology options, not only during their operation but also during their whole life cycle. The analysis has been performed by integrating the life cycle assessment concept into a linear programming model for the yearly decisions on which options should be used to minimize the electricity generation costs. The model has been applied for the case of Greece for the years 2012–2050 and has led to several interesting results. First, most of the new generating capacity should be renewable (mostly biomass and wind), while natural gas is usually the only conventional fuel technology chosen. If externalities are considered, wind energy increases its share and hydro-power replaces significant amounts of biomass-generated energy. Furthermore, a sensitivity analysis has been performed. One of the most important findings is that natural gas increases its contribution when externalities are increased. Summing-up, external cost has been found to be a significant percentage of the total electricity generation cost for some energy sources, therefore significantly changing the ranking order of cost-competitiveness for the energy sources examined.

14/02934 Integrated well-to-wheel assessment of biofuels combining energy and emission LCA and welfare economic cost benefit analysis

Møller, F. *et al. Biomass and Bioenergy*, 2014, 60, 41–49.

The present study integrates material-based life cycle analysis (LCA) with welfare economic cost benefit analysis (CBA) to evaluate resource and environmental consequences as well as welfare consequences for society of introducing biofuels in the Danish road transport sector. The integrated method focus on fossil energy consumption, CO_2 emissions and total welfare economic changes within the whole LCA flow chain comprising both production of biomass and subsequent conversion into biofuel and combustion in vehicles. With regard to consequences for fossil energy consumption a global delimitation is used whereas only CO_2 emissions and welfare economic consequences within Danish borders are included in the analysis. Consequently, calculated emission and welfare economic consequences can be interpreted as the consequences for Denmark of producing and using biofuels from biomass grown on Danish farm land. The method is applied with regard to production of rape diesel (rape methyl ester), first-generation ethanol from wheat and second-generation ethanol based on straw. Advantages and disadvantages of the LCA based material flow approach and the welfare economic based CBA approach are discussed. The influence of uncertainties on the results is evaluated illustrating the importance of paying attention to assumptions with regard to substitution of other products and resources and with regard to their relative prices.

14/02935 Life cycle analysis of internal combustion engine, electric and fuel cell vehicles for China

Wang, D. *et al. Energy*, 2013, 59, 402–412.

Efficient and clean vehicles are highly demanded in China due to the increasing severe energy and environmental issues. In this study, based on the current (2009) and predicted (2020) situations of China, internal combustion engine vehicles (ICEVs), electric vehicles (EVs) and fuel cell vehicles (FCVs) are assessed through a life cycle analysis in terms of energy consumption, carbon emission, PM2.5 and well-to-wheel efficiency. The results show that FCVs using hydrogen from natural gas reforming (no electrolysis of water) are suitable for the short-term energy conservation and emission reduction in China, because they are less dependent on the Chinese electricity mix dominated by coal-fired energy. EVs and FCVs using water-electrolysed hydrogen powered by the Chinese electricity grids may cause serious energy and environmental issues, and the requirements of the electricity mix before the commercialization of these vehicles are estimated. For the vehicle price, ICEVs and EVs (with subsidies) are less expensive than FCVs in 2009, but it remains debated for 2020 with the development of technology and change of policy. This analysis is of significant importance in directing the energy, environment and transportation policy for sustainable development in China.

14/02936 Life cycle assessment of a building integrated concentrated photovoltaic scheme

Menoufi, K. *et al. Applied Energy*, 2013, 111, 505–514.

A life cycle assessment (LCA) study of a building integrated concentrated photovoltaic (BICPV) scheme at the University of Lleida, Spain, was conducted. Assumptions for representing a real building are considered, and a comparison to a hypothetical conventional building integrated photovoltaic (BIPV) scheme is established. A life cycle impact assessment (LCIA) is performed using the EI99 methodology, which is considered to be the reference. In addition, the environmental impact is re-evaluated using the EPS 2000 methodology. The results show a significant extent of the environmental benefits gained using the BICPV schemes. Some differences in the components impact contribution percentages are noticed between the EI99 and the EPS 2000 methodologies. Nevertheless, both methodologies coincide in the conclusion of the significant environmental impact reduction reached from replacing the conventional BIPV schemes with the BICPV ones. Recommendations for future work and system improvements are discussed.

14/02937 Life cycle assessment of coupling household biogas production to agricultural industry: a case study of biogas-linked persimmon cultivation and processing system

Chen, B. and Chen, S. *Energy Policy*, 2013, 62, 707–716.

Biogas plant construction has been boosted in rural China not only due to the immediate merit from biogas production but also the succeeding benefit from by-product utilization in agro-industry, both of which are significant strategies to address energy shortage and global warming issues. However, little work has been done to evaluate the coupling of biogas projects to traditional agrosystems from a life-cycle perspective, which is most important in process and system optimization in different senses. By taking persimmon cultivation and processing with support from a household biogas plant as a case study, this study conducts a life-cycle assessment of coupling biogas production to agro-industry in terms of energy, environmental and economic performance. The results suggest that each production stage following the biogas/digestate utilization chain (biogas operation–persimmon cultivation–product processing) is beneficial across all three aspects. However, a trade-off only exists in utilizing digestate as top-dressing and employing biogas utilization as engine fuel, while biogas application in fresh-keeping and digestate reuse as base fertilizer fails to increase either energy production or greenhouse gas emissions mitigation. The coupled system can hopefully be optimized through increasing fermentation efficiency and the joint operation of biogas digesters.

14/02938 Life cycle assessment of stand-alone photovoltaic (SAPV) system under on-field conditions of New Delhi, India

Sharma, R. and Tiwari, G. N. *Energy Policy*, 2013, 63, 272–282.

In this paper, a life cycle analysis has been carried out to evaluate overall performance of given rated stand-alone solar photovoltaics (SAPV) in terms of basic energy matrices, life cycle cost analysis and earned carbon credit. Further, the experimentally calculated actual on-field life cycle performance results of an existing outdoor SAPV system (almost 20 years old) have been represented with respect to the potential (maximum) performance of the same SAPV system estimated under the same environmental conditions of solar intensity, ambient temperature and PV operating temperature as obtained during actual on-field performance evaluations. This new approach of overall performance evaluation by considering the on-field SAPV system installation as new (i.e. with potential maximum performance) and old (i.e. with actual performance) under same environmental conditions provides an inclusive comparative life cycle assessment of on-field PV systems.

14/02939 Life cycle energy and greenhouse gas emissions from transportation of Canadian oil sands to future markets

Tarnoczi, T. *Energy Policy*, 2013, 62, 107–117.

Transportation diversification of oil sands is important in preventing discounted crude pricing. Current life cycle assessment (LCA) models that assess greenhouse gas (GHG) emissions from crude oil transportation are linearly-scale and fail to account for project specific details. This research sets out to develop a detailed LCA model to compare the energy inputs and GHG emissions of pipeline and rail transportation for oil sands products. The model is applied to several proposed oils sands transportation routes that may serve as future markets. Comparison between transportation projects suggest that energy inputs and GHG emissions show a high degree of variation. For both rail and pipeline transportation, the distance over which the product is transported has a large impact on total emissions. The regional electricity grid and pump efficiency have the largest impact on pipeline emissions, while train engine efficiency and bitumen blending ratios have the largest impact on rail transportation emissions. LCA-based GHG regulations should refine models to account for the range of product pathways and focus efforts on cost-effective emissions reductions. As the climate-change impacts of new oil sands transportation projects are considered, GHG emissions boundaries should be defined according to operation control.

14/02940 Life cycle GHG analysis of rice straw bio-DME production and application in Thailand

Silalertruksa, T. *et al. Applied Energy*, 2013, 112, 560–567.

Thailand is one of the leading countries in rice production and export; an abundance of rice straw, therefore, is left in the field nowadays and is commonly burnt to facilitate quick planting of the next crop. The study assesses the life cycle greenhouse gas (GHG) emissions of using rice straw for bio-dimethyl ether (DME) production in Thailand. The analysis is divided into two scenarios of rice straw bio-DME utilization: used as an automotive fuel for diesel engines and used as a liquefied petroleum gas (LPG) supplement for household applications. The results reveal that that utilization of rice straw for bio-DME in the two scenarios could help reduce GHG emissions by around 14–70% and 2–66%, respectively, as compared to the diesel fuel and LPG substituted. In case rice straw is considered as a by-product of rice cultivation, the cultivation of rice straw will be the major source of GHG emission contributing around 50% of the total GHG emissions of rice straw bio-DME production. Several factors that can affect the GHG performance of rice straw bio-DME production are discussed along with measures to enhance GHG performance of rice straw bio-DME production and utilization.

14/02941 Life cycle inventory development for corn and stover production systems under different allocation methods

Murphy, C. W. and Kendall, A. *Biomass and Bioenergy*, 2013, 58, 67–75.

Agricultural residues, particularly corn stover, are a promising feedstock for bioenergy systems. To analyse these systems in a life cycle framework, environmental impacts from cultivation and harvest must be allocated to the resulting products, corn grain and stover. This paper explores three approaches to allocation for corn and stover: economic and energy-based allocation, as well as a subdivision approach, which assigns to stover only those additional activities caused by its harvest. This study develops a life cycle inventory for corn production based on average US agronomic data and then applies the three allocation methods to produce a life cycle inventory for stover. This inventory contains over 1100 environmental flows and is available in the online Supplementary material. This analysis shows that economic allocation and subdivision assign the least impact to stover (14–15%), energy-based allocation the most (30%). One hectare of corn and stover production emits approximately 2.5 tonnes of carbon equivalent and requires approximately 23 GJ of fossil energy. Value-based allocation methods, like energy and economic allocation, may be most appropriate when they reflect the goals of the production system. In addition, value-based methods are typically simple to apply, and thus may be more transparent for those interpreting a study. Subdivision, as applied in this study, reflects the consequences of changing the existing corn production systems, may require more data, and might be most appropriate for near-term prospective analyses; such as those that question whether adding cellulosic ethanol production to existing corn production systems yields environmental benefits. Thus, the selection of an allocation approach should hinge on the intent of the study.

14/02942 Life-cycle greenhouse gas emissions and energy balances of a biodiesel production from palm fatty acid distillate (PFAD)

Cho, H. J. *et al. Applied Energy*, 2013, 111, 479–488.

Life-cycle greenhouse gas (GHG) emissions and net energy ratio (NER) have been evaluated for the production of palm biodiesel from palm fatty acid distillate (PFAD) which is a by-product in the refining process. For the case that PFAD is regarded as a processing residue, GHG emissions associated with biodiesel production in the considered process is 86.5% less than that of fossil diesel, which surpasses even the threshold of year 2018 of the Renewable Energy Directive (RED) of the European Union (EU). In the present study, it is also shown that the value of the NER is 3.23, which means that the energy yield from palm methyl ester (PME) production from PFAD is around three times larger than the input of fossil energy in the production. In conclusion, the palm biodiesel from PFAD can be one of various alternatives to the 'conventional' palm biodiesel which is made of refined palm oil, and sustainability issues and ethical problems can be considerably minimized with the strategic utilization of palm biodiesel produced from PFAD.

14/02943 Relative importance of electricity sources and construction practices in residential buildings: a Swiss-US comparison of energy related life-cycle impacts

Mosteiro-Romero, M. *et al. Energy and Buildings*, 2014, 68, 620–631.

Comparisons of buildings in similar climates built in accordance with different regional construction practices and building rating systems can provide useful insights in sustainable design practices. The objectives of this study were: (1) to perform energy-related life cycle assessments of a typical LEED-H (Leadership in Energy and Environmental Design for Homes) single-family home in New Jersey, USA, and a typical Minergie-P single-family home in Chur, Switzerland; and (2) to assess the effect of rating systems and construction practices on the buildings' environmental impacts. Inventory data were obtained from the Ecoinvent 2.2 database with a replacement of the western European electricity mix with the US or New Jersey electricity mix for the New Jersey home. The Swiss building performed better regarding non-renewable energy consumption, global warming potential and acidification potential mainly due to the geothermal heat pump and the Swiss electricity mix while there was less of a difference regarding ozone layer depletion potential and eutrophication potential. The influence of electricity sources exceeded the effects of longer building life time or the removal of the Swiss basement. Regional building practices, local codes and environmental policies should take the electricity mix into account because it is so important.

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Supplies, policy, economics, forecasts

14/02944 A public choice view on the climate and energy policy mix in the EU – how do the emissions trading scheme and support for renewable energies interact?

Gawel, E. *et al. Energy Policy*, 2014, 64, 175–182.

This study analyses the rationale for an energy policy mix when the European Union emissions trading scheme (EU ETS) is considered from a public choice perspective. That is, the authors argue that the economic textbook model of the ETS implausibly assumes: (1) efficient policy design and (2) climate protection as the single objective of policy intervention. Contrary to these assumptions, the authors propose that the ETS originates from a political bargaining game within a context of multiple policy objectives. In particular, the emissions cap is negotiated between regulators and emitters with the emitters' abatement costs as crucial bargaining variable. This public choice view yields striking implications for an optimal policy mix comprising policies for supporting renewable energy sources. Whereas the textbook model implies that the ETS alone provides sufficient climate protection, this analysis suggests that support for renewable energies (1) contributes to a more effective ETS design and (2) may even increase the overall efficiency of climate and energy policy if other externalities and policy objectives besides climate protection are considered. Thus, this analysis also shows that a public choice view not necessarily entails negative evaluations concerning efficiency and effectiveness of a policy mix.

14/02945 An empirical study of electricity and gas demand drivers in large food retail buildings of a national organisation

Spyrou, M. S. *et al. Energy and Buildings*, 2014, 68, 172–182.

Food retail buildings account for a measurable proportion of a country's energy consumption and resultant carbon dioxide emissions. Energy-operating costs are key business considerations. Increased understanding of end-use energy demands in the food sector can enable development of effective benchmarking systems to underpin energy management tools. This could aid identification and evaluation of interventions to reduce operational energy demand. While there are a number of theoretical and semi-empirical benchmarking and thermal modelling tools that can be used for food retail building stocks, these do not readily account for the variance of technical and non-technical factors that can influence end-use demands. This paper discusses the various drivers of energy end-uses of typical UK grocery shops. It reports on an empirical study of one organization's hypermarket stock to evaluate the influence of various factors on annual store electricity and gas demands. Multiple regression models are discussed in the context of the development and application of a methodology for estimating annual energy end-use demand in food retail buildings. The established models account for 75% of the variation in electricity demand, 50% of the variation in gas demand in stores without combined heat and power (CHP) and 77% of the variation in gas demand in stores with CHP.

14/02946 Assaí – an energy view on an Amazon residue

Teixeira, M. A. *et al. Biomass and Bioenergy*, 2013, 58, 76–86.

This paper analysed the technical and economic feasibility of electricity generation using the residues from the exploitation of Assaí, an (*Euterpe oleracea*, Mart). Assaí biomass characteristics as fuel were reviewed based on available literature and its availability assessed. The profile of a typical industrial processing unit was described. The electricity generation cost for a 1 MW conversion systems, considering $5.5\,\text{US\$}\,\text{t}^{-1}$ biomass price, were evaluated: conventional steam cycle with backpressure turbine ($66.97\,\text{US\$}\,\text{MWh}^{-1}$), steam cycle with extraction condensation turbine ($92.11\,\text{US\$}\,\text{MWh}^{-1}$), organic Rankine cycle ($122\,\text{US\$}\,\text{MWh}^{-1}$) and a gasifier/internal combustion engine set ($102\,\text{US\$}\,\text{MWh}^{-1}$). Based on financial performance, back-pressure steam turbine was the best option, and gasifier/internal combustion should be further considered due its operation flexibility. For any system, minimal electricity commercialization price for economic feasibility found was $150\,\text{US\$}\,\text{MWh}^{-1}$.

14/02947 Assessment of the status and outlook of biomass energy in Jordan

Al-Hamamre, Z. *et al. Energy Conversion and Management*, 2014, 77, 183–192.

This work investigates the status and potential of using biomass as an energy source in Jordan. The amount of waste and residue in Jordan for 2011 is estimated to be 6.680 million tons. Two scenarios were investigated: biogas production and thermal treatment. The amount of biogas that can be produced from various biomass sources in Jordan is estimated at 428 MCM. The equivalent annual power production is estimated at 698.1 GW h. This is equivalent to about 5.09% of the consumed electricity (13,535 GW h) and 39.65% of the imported electricity in 2011. The alternative scenario of thermal treatment was investigated. The total theoretical thermal energy that can be obtained, assuming 70% conversion efficiency, is equivalent to 779,000 toe (5.33 million barrels of crude oil) which amounts to 10.2% of the total primary energy consumed in 2011. Due to biomass collection and recovery challenges, the energy availability factor varies for the different resources. Hence, contribution of the different biomass resources can significantly vary.

14/02948 Biomass logistics: financial & environmental costs. Case study: 2 MW electrical power plants

Ruiz, J. A. *et al. Biomass and Bioenergy*, 2013, 56, 260–267.

Biomass is so diverse that special care must always be taken in designing plants to handle biomass-based fuels and in the process for its collection, preparation and transportation, because its energy density is such that far greater volumes need to be transported than in the case of fossil fuels. This means higher costs and more associated CO_2 emissions. This paper examines the following points concerned with the logistics of biomass: optimum biomass transport distances to plants, transport costs, CO_2 emissions relative to CO_2 avoided and the surface areas required to grow or collect biomass. Particular emphasis is placed on the logistics of biomass-fired electric power plants rated at 2 MW electrical, a size that enables electric power distribution to be decentralized. The findings reveal that the maximum cost of logistics (not including any collection and preparation stages) is €11.05/tonne, with emissions amounting to 0.69% of the total CO_2 avoided, for the worst-case scenario of distances averaging 100 km around the plant.

14/02949 China's sovereign wealth fund investments in overseas energy: the energy security perspective

Sun, X. *et al. Energy Policy*, 2014, 65, 654–661.

Sovereign wealth funds (SWFs) are state-owned investment funds that invest in real and financial assets. Since the global financial crisis in 2008, SWFs' investments have resulted in national security concerns of host countries because SWFs continue to expand rapidly and have become increasingly active in real-time strategic transactions. Given this background, China, which has the biggest SWF in the world, is facing severe challenges of energy resources shortages while its plan is to accomplish social and economic development goals. Energy security is a key driving force of the energy investment policy of China's SWFs. This makes the SWF investments more complicated and more politically sensitive. The combination of sovereign rights and the strategic importance of energy also makes geopolitics more complicated and brings more uncertainty to SWF investments. This article explores the relationship between energy security and energy investments of China's SWFs. It is recognized that the energy investment of SWFs must follow a sustainable path to coordinate energy security, economic growth, return on investment and national security concerns. Government policymakers are urged to balance the financial and political returns on SWFs against potential negative effects. The conclusion presents insights for policymakers, energy scholars and SWF researchers.

14/02950 Development of an energy monitoring system for large public buildings

Zhao, L. *et al. Energy and Buildings*, 2013, 66, 41–48.

Building energy consumption is an important component of the total social energy consumption, especially for large public buildings in China. Building energy conservation is one valid method for increasing energy efficiency. In order to locate the status of energy consumption for large public buildings, such as supermarkets, government office buildings, hospital and campus buildings, an Internet-based energy monitoring system was developed. The implementation of this system was introduced in detail, including the principle of selecting monitoring points at the bottom layer, the design of a data collector with storage function avoiding data loss caused by network faults, and the development of database and application software at the top layer. The monitoring platform releases the energy consumption data on the web, so the authorized users can access the data at any time and any place through Internet. In addition, the data display system is given in form of graph-charts or tables, so users can choose any kind of data they want to see, either instant values uploaded every 5 min or historic data uploaded every hour, day and month. The platform has been used in some large public buildings in Liaoning Province in China over 2 years, and the results confirm its feasibility and validity.

14/02951 Electricity-generation mix considering energy security and carbon emission mitigation: case of Korea and Mongolia

Ryu, H. *et al. Energy*, 2014, 64, 1071–1079.

To compare electricity-generation fuel mixes in two countries with multiple energy policy goals and unique circumstances, the authors look at three scenarios reflecting the carbon emissions mitigation targets, differences in energy security levels, and electricity-generating costs of each nation. Korea and Mongolia show clear differences in electricity-generation structure related to import dependency, the potential of renewable energy and threats to energy security. These variations lead to different decisions on the power-generation fuel mix plan. Use of fossil fuel resources in Korea results in carbon dioxide emissions and energy insecurity, while in Mongolia carbon emissions, also from fossil fuels, and energy insecurity are separate concerns as Mongolia domestically operates coal-fired power plants and imports electricity. Policies targeting two objectives, carbon emissions mitigation and energy security improvement, show complementarity in Korea as fossil fuels are replaced by renewables or nuclear power, but represent trade-offs in Mongolia as emissions mitigation and improved energy security cannot be achieved with one strategy. In conclusion, national plans to achieve two goals differ by country: in Korea, the appropriate portion of nuclear energy is the determining policy factor. In Mongolia, carbon capture and storage is the clear alternative for mitigating carbon emissions despite large renewables potential.

14/02952 Embodied and operational energy for new-build housing: a case study of construction methods in the UK

Iddon, C. R. and Firth, S. K. *Energy and Buildings*, 2013, 67, 479–488.
In this study, a building information model (BIM) tool is developed to simultaneously estimate embodied and operational carbon over a 60-year life span for a typical four-bedroom detached house in the UK. Using the tool, four different construction scenarios are evaluated, representing a range of current construction methods used in present-day house building in the UK. The results show that cradle-to-gate embodied carbon represents 20–26% of the total 60-year carbon emissions, with operational carbon representing 74–80% of total emissions. Construction scenarios that reduce operational carbon by improving the thermal envelope led to a 1–13% increase in embodied carbon but a 4–5% decrease in operational carbon compared to the base case construction method. Approaches to reduce embodied carbon in new-build housing are also studied and a 24% reduction is demonstrated through building fabric changes. The study recommends that a universally robust methodology for measuring embodied carbon will enable design decisions to be taken to reduce whole-life carbon emissions through improved choice of materials. Due to material changes impacting on the thermal characteristics of a dwelling, and to an extent the structural characteristics, an integrated BIM tool will be essential in quickly establishing whole-life carbon impacts during the design stage.

14/02953 Energy and economic evaluation of a poplar plantation for woodchips production in Italy

Manzone, M. *et al. Biomass and Bioenergy*, 2014, 60, 164–170.
In Europe, farmers prefer the very short rotation coppice cultivation model, with a very high plant density (5500–14,000 p ha^{-1}) and a harvesting cycle of 1–4 years; while in Italy, recently, the farmers prefer the short rotation coppice (SRC) method, with a high plant density (1000–2000 p ha^{-1}) and a harvesting cycle of 5–7 years. This is because the most recent poplar hybrids have enhanced productivity and improved the biomass quality (calorific value), as a result of a better wood/bark ratio. In order to evaluate, from the energy and economic point of view, a poplar SRC, in the River Po valley, an *ad hoc* study was made and a specific model was developed. On the basis of this cultivation technique, an energy and economic evaluation of a poplar SRC in northern Italy was realized. In detail, were considered data of poplar growth, in a plantation for the production of 6 year whips, in western Po valley, considering a SRC duration of 6 years and a biomass (15 Mg ha^{-1} dry matter per year) harvest at the end of cycle (6 years). In this computing system it was pointed out that the SRC is very interesting from an energy point of view, since the output/input ratio results to be higher than 18. The same is not true for the poplar SRC from an economic point of view. In order to obtain economic SRC sustainability, the biomass price should be at least €115/Mg dry matter. A large biomass diffusion will be possible only with an increase of the biomass market value, or with economic sustain for its production.

14/02954 Energy and exergy utilization efficiencies and emission performance of Canadian transportation sector, 1990–2035

Motasemi, F. *et al. Energy*, 2014, 64, 355–366.
Transportation in Canada is the second largest energy-consuming sector which accounted for 30% of the total energy consumption of the country in 2009. The purpose of this work was to analyse the energy, exergy and emission performance for four different modes of transport (road, air, rail and marine) from 1990 to 2035. For the historical period, the estimated overall energy efficiency ranges from 22.41% (1991) to 22.55% (2006) with a mean of $22.48 \pm 0.07\%$ and the overall exergy efficiency ranges from 21.61% (2001) to 21.87 (2006) with a mean of $21.74 \pm 0.13\%$. Energy and exergy efficiencies may reach 20.95% and 20.97%, respectively, in 2035 based on forecast data. In comparison with other countries, the authors found that in 2000, the overall energy and exergy efficiencies for Canadian transportation sector were higher than Jordan, China, Norway and Saudi Arabia but lower than Turkey and Malaysia. Between 1990 and 2009, the highest amount of emissions produced in each subsector were as follows: road CO_2 (80%), NO_x (72%), and CO (carbon monoxide) (96%); air SO_2 (86%); rail NO_x (6%) and marine NO_x (7%). The road subsector produced the largest amount of emissions.

14/02955 Energy management strategies for commercial greenhouses

Vadiee, A. and Martin, V. *Applied Energy*, 2014, 114, 880–888.
The growth in population and the ever-increasing development of new production technologies leads to a rise in energy use for the agricultural industry. Although the greenhouse is one of the most energy intensive sectors in the agricultural industry, it is important because of its ability to intensify production. This paper has assessed energy management strategies (including single and combined energy conservation opportunities), with special emphasis on Nordic climates, where fossil fuel-based heating is still significant, despite a recent conversion to biomass boilers. The results show that the 'double thermal screen' and 'double glazing' with 60% reduction in energy demand are the most effective single opportunity for energy conservation. However, the highest improvement (80%) is obtainable using the closed greenhouse concept, with a potential payback of 5–6 years under favourable conditions. It can be concluded that some of the single opportunities can be more practical in terms of their payback period in comparison to a complex concept, requiring a combination of measures, such as the closed greenhouse.

14/02956 EROI of different fuels and the implications for society

Hall, C. A. S. *et al. Energy Policy*, 2014, 64, 141–152.
All forms of economic production and exchange involve the use of energy directly and in the transformation of materials. Until recently, cheap and seemingly limitless fossil energy has allowed most of society to ignore the importance of contributions to the economic process from the biophysical world as well as the potential limits to growth. This paper centres on assessing the energy costs of modern-day society and its relation to gross domestic product. The most important focus is the characteristics of major energy sources including each fuel's energy return on investment (EROI). The EROI of the most important fuels is declining and most renewable and non-conventional energy alternatives have substantially lower EROI values than traditional conventional fossil fuels. At the societal level, declining EROI means that an increasing proportion of energy output and economic activity must be diverted to attaining the energy needed to run an economy, leaving less discretionary funds available for 'non-essential' purchases which often drive growth. The declining EROI of traditional fossil fuel energy sources and the effect of that on the world economy are likely to result in a myriad of consequences, most of which will not be perceived as good.

14/02957 Estimating the impact of the financial development on energy consumption: evidence from the GCC (Gulf Cooperation Council) countries

Al-mulali, U. and Lee, J. Y. M. *Energy*, 2013, 60, 215–221.
This study investigates the impact of the financial development on energy consumption in the Gulf Cooperation Council (GCC) countries. The panel data methodology was utilized taking the period 1980–2009. By using Pedroni cointegration test, it was found that energy consumption (LEC), the financial development (LFD), gross domestic product (LGDP), urbanization (LUR) and total trade (LTD) are cointegrated. Furthermore, the panel dynamic ordinary least squares revealed that LFD, LGDP, LUR and LTD have a long run positive effect on LEC. The Granger causality results show a bi-directional positive relationship between LEC and LGDP, LFD and LGDP, LTD and LGDP, LTD and LFD, LTD and LUR and between LTD and LTD. In addition, a one-way positive causal relationship was found from LFD to LEC and from LUR to LEC. The study revealed that the financial development is one of the factors that increased energy consumption in the GCC in the short and the long run. From the findings of this study, a number of recommendations were formulated regarding the GCC policy makers to help reducing their energy consumption.

14/02958 HeatWave: a handheld 3D thermography system for energy auditing

Vidas, S. and Moghadam, P. *Energy and Buildings*, 2013, 66, 445–460.
Energy auditing is an effective but costly approach for reducing the long-term energy consumption of buildings. When well executed, energy loss can be quickly identified in the building structure and its subsystems. This then presents opportunities for improving energy efficiency. The authors present a low-cost, portable technology called 'HeatWave' which allows non-experts to generate detailed three-dimensional (3D) surface temperature models for energy auditing. This handheld 3D thermography system consists of two commercially available imaging sensors and a set of software algorithms which can be run on a laptop. The 3D model can be visualized in real-time by the operator so that they can monitor their degree of coverage as the sensors are used to capture data. In addition, results can be analysed offline using the proposed 'Spectra' multispectral visualization toolbox. The presence of surface temperature data in the generated 3D model enables the operator to easily identify and measure thermal irregularities such as thermal bridges, insulation leaks, moisture build-up and heating, ventilation and air-conditioning faults. Moreover, 3D models

generated from subsequent audits of the same environment can be automatically compared to detect temporal changes in conditions and energy use over time.

14/02959 Long term building energy demand for India: disaggregating end use energy services in an integrated assessment modeling framework

Chaturvedi, V. *et al. Energy Policy*, 2014, 64, 226–242.

With an increasing population, income and urbanization, meeting the energy service demands for the building sector will be a huge challenge for India's energy policy. Although there is broad consensus that the Indian building sector will grow and evolve over the coming century, there is little understanding of the potential nature of this evolution over the longer term. The present study uses a technologically detailed, service-based building energy model nested in the long-term, global, integrated assessment framework, GCAM, to produce scenarios of the evolution of the Indian buildings sector up through the end of the century. The results support the idea that as India evolves toward developed country per-capita income levels, its building sector will largely evolve to resemble those of the currently developed countries (heavy reliance on electricity both for increasing cooling loads and a range of emerging appliance and other plug loads), albeit with unique characteristics based on its climate conditions (cooling dominating heating and even more so with climate change), on fuel preferences that may linger from the present (for example, a preference for gas for cooking), and vestiges of its development path (including remnants of rural poor that use substantial quantities of traditional biomass).

14/02960 Long-term fuel demand: not only a matter of fuel price

Lampin, L. B. A. *et al. Energy Policy*, 2013, 62, 780–787.

This paper analyses the non-energy determinants of transport-related fuel consumption and in particular investigates the role of housing price trajectories in driving long-run demand for motor fuel. To this aim it develops a dynamic modelling framework and takes the next step of testing it for cointegration. French data spanning 50 years up to 2009 are used. It is found that when facing an increase of dwellings' real price, fuel demand remains stable in the short term, whereas it increases significantly in the long term. The results reflect the role of spatial organization in the formation of energy demand through the trade-off between housing prices and commuting costs. The modelling framework is then extended to assess the potential interest of combining housing policies aiming to drive down housing prices with carbon taxes so as to achieve a wide range of fuel demand reduction targets. It is shown that the relative contribution of housing policies increases with the degree of ambition of fuel consumption reduction targets.

14/02961 Long-term optimization of United Arab Emirates energy future: policy implications

Mondal, M. A. H. *et al. Applied Energy*, 2014, 114, 466–474.

This paper presents an evaluation of future energy-supply strategies for the United Arab Emirates' (UAE) power sector. This paper also identifies the prospects for the further economic development of the country while addressing energy security issues and mitigating environmental impacts. It explores technology choices to meet the future demand in the most cost-efficient way based on existing and innovated technologies. The analyses are done for the UAE energy system by applying the MARKAL model. Different policies such as a CO_2 emissions reduction constraint, renewable energy production targets and subsidy minimization through international benchmarking for domestic gas prices are applied for this analysis. The results show that the alternative policy scenarios directly allocate clean advanced and renewable technologies to generate electricity. The alternative policy scenarios reduce CO_2 emissions in the power sector. The simulation results from model show that the alternative sustainable energy development policies expected total system cost is not significantly higher. The cumulative system cost increases, relative to the base scenario by 9% and 11% for CO_2 emissions reduction and renewable target production scenarios, respectively. Use of primary resources to meet the demand is reduced and the supply of primary energy resources is diversified.

14/02962 Long-term transport energy demand and climate policy: alternative visions on transport decarbonization in energy-economy models

Pietzcker, R. C. *et al. Energy*, 2014, 64, 95–108.

Decarbonizing transport will be necessary to limit global warming below 2 °C. Due to persistent reliance on fossil fuels, it is posited that transport is more difficult to decarbonize than other sectors. To test this hypothesis, this study compares long-term transport energy demand and emission projections for China, USA and the rest of the world using five large-scale energy-economy models. The authors diagnosed the model's characteristics by subjecting them to three climate policies. They then systematically analysed mitigation levers along the chain of causality from mobility to emissions, finding that some models lack relevant mitigation options. The results partially confirm that transport is less reactive to a given carbon tax than the non-transport sectors: in the first half of the century, transport mitigation is delayed by 10–30 years compared to non-transport mitigation. At high carbon prices towards the end of the century, however, the three global models achieve deep transport emission reductions by >90% through the use of advanced vehicle technologies and low-carbon primary energy; especially biomass with carbon capture and sequestration plays a crucial role. The extent to which earlier mitigation is possible strongly depends on implemented technologies and model structure. Compared to the global models, the two partial-equilibrium models are less flexible in their reaction to climate policies.

14/02963 Planning of regional energy systems: an inexact mixed-integer fractional programming model

Zhu, H. *et al. Applied Energy*, 2014, 113, 500–514.

In this study, an inexact mixed-integer fractional energy system planning (IMIF-EP) model is developed for supporting sustainable energy system management under uncertainty. Based on a hybrid of interval-parameter programming (IPP), fractional programming (FP) and mixed integer linear programming (MILP) techniques, IMIF-EP can systematically reflect various complexities in energy management systems. It not only handles imprecise uncertainties and dynamic features associated with power generation expansion planning, but also optimizes the system efficiency represented as output/input ratios. An interactive transform algorithm is proposed to solve the IMIF-EP model. For demonstrating effectiveness of the developed approach, IMIF-EP is applied to support long-term planning for an energy system. The results indicate that interval solutions obtained from IMIF-EP can provide flexible schemes of resource allocations and facility expansions towards sustainable energy management (SEM) under multiple complexities. A comparative economical energy management (EEM) system is also provided. Compared with least-cost models that optimize single criterion, IMIF-EP can better characterize practical energy management problems by optimizing a ratio between criteria of two magnitudes. In application, IMIF-EP is advantageous in balancing conflicting objectives and reflecting complicated relationships among multiple system factors.

14/02964 Role of renewable energy policies in energy dependency in Finland: system dynamics approach

Aslani, A. *et al. Applied Energy*, 2014, 113, 758–765.

This study discusses the role of diversification on dependency and security of energy supply. As part of this, a system dynamics model with especial focus on the role of renewable energy resources (as a portfolio) on Finland's energy dependency was developed. The study also considers the research gap that exists in the system dynamics modelling of energy security investigations. A causal loops diagram and a system dynamics model evaluated three different Finnish scenarios of renewable energy policies by 2020. The analysis shows that despite 7% electricity/heat consumption growth by 2020 in Finland, dependency on imported sources will decrease between 1% and 7% depend on the defined scenarios. This model not only helps decision makers to test their scenarios related to renewable energy polices, it can be implemented by other countries.

14/02965 Scales, strategies and actions for effective energy planning: a review

Pasimeni, M. R. *et al. Energy Policy*, 2014, 65, 165–174.

This paper is a review of the most recent literature on the interaction between climate change, land-use and energy, based on the analysis of papers collected through the most relevant scientific literature databases. A total of 114 papers published between 2000 and 2011 were reviewed. The aims of this review are: in general (1) to identify the different research topics that have been developed related to the interaction between climate change, land-use and energy; more specifically, (2) to analyse what are the most suitable spatial and temporal scales of investigation to focus on for actions and strategies to reduce critical issues in the field of energy and environment; (3) to identify which actions and strategies are deemed as the most appropriate to mitigate critical issues in energy and environment; and given the research gaps found in the review, (4) to propose research recommendations in the context of effective climate-energy planning. The authors argue that there are certain gaps and needs for a 'nested' environmental governance. It is necessary to understand how different environmental policies overlap and how they can be integrated in order to verify whether there are conflicting targets that may negate each other in the long term.

14/02966 Spatial planning as a driver of change in mobility and residential energy consumption

Dujardin, S. *et al. Energy and Buildings*, 2014, 68, 779–785.

This paper analyses the impact of territorial structures on energy consumption in the Walloon region of Belgium. The rationale for this research is to consider the long-term influence of spatial planning decisions on energy consumption in both residential building stock and home-to-work commuting. The analysis has been conducted on a regional scale (16,844 km^2) and includes urban, peri-urban and rural settlements. Those settlements that perform well in mobility also appear to perform well in terms of building energy consumption. Even though this is not generally the case, it further reveals that some rural settlements characterized by low density show good performance in terms of energy efficiency. This permits a much more progressive approach in terms of spatial planning, whereby compact cities may be viewed as part of the solution, albeit not the whole solution.

14/02967 The development of smart homes market in the UK

Balta-Ozkan, N. *et al. Energy*, 2013, 60, 361–372.
Smart homes will be a key component of smart grids as without them the functionalities and capabilities offered at network level will not be realized fully by householders. Yet an extensive body of literature focuses on energy consumption and management services via various demand side-management programmes and informs us of a significant variation in the realization of these benefits to reduce demand. However services which can be enabled via smart technology are much broader than simply energy consumption and management, spanning from assisted living to security to remote monitoring, control and management of appliances and devices. Using a combination of in-depth deliberative public workshops, expert interviews and a review of the existing literature, this paper gives an overview of services that smart homes can offer and reveals key barriers to smart home adoption such as interoperability, deregulated electricity supply industry, UK housing stock characteristics, tenure as well as reliability, security, and cost of smart technologies. The findings indicate a need for a holistic view for the design and delivery of smart home services so that consumers are offered integrated services across energy consumption and management to air quality management to security, allowing for individual or tailored services for householders.

14/02968 The European framework for energy and climate policies

Helm, D. *Energy Policy*, 2014, 64, 29–35.
European energy and climate change policy rests on two main pillars: the internal energy market (IEM) and the climate change package (CCP). The IEM aimed at third party access and unbundling, neglects the physical infrastructure and the basis for asset valuations and hence the harmonization of network charges. The European Commission plans to complete the IEM by 2014 – almost a quarter of a century after embarking on the policy. Yet even if all the IEM directives are implemented, the European Union (EU) will remain far from a single competitive market. The CCP was grounded on short-term targets (the 2020–20–20 programme) on the assumption that fossil fuel prices would rise, making renewables competitive, and hence yielding a competitive advantage to the EU. The EU emissions trading scheme (ETS) was intended to lead the way to a global trading system and an international agreement at Copenhagen. The EU has reduced the production of carbon dioxide emissions, but only as a result of deindustrialization and slow growth, and at the expense of rising carbon dioxide consumption. Renewables have not led to green growth, but rather to a further eroding of competitiveness. The EU ETS price has collapsed. In order for the EU to put the IEM and the CCP back on track, both need to be radically reconsidered. The IEM requires a refocusing on physical infrastructure, common accounting rules and an EU-wide approach to capacity markets and renewables trading. The CCP requires a refocusing on carbon dioxide consumption, on limiting the 'dash for coal', and on future rather than current renewables.

14/02969 The impacts of carbon tax on energy intensity and economic growth – a dynamic evolution analysis on the case of China

Fang, G. *et al. Applied Energy*, 2013, 110, 17–28.
This paper examines the impacts of carbon tax on energy intensity and economic growth in a novel four-dimensional energy-saving and emission-reduction system with carbon tax constraints. Based on Lyapunov exponents and bifurcation diagrams, the dynamic behaviour of the system is analysed. The quantitative coefficients of the actual system are identified by artificial neural network. A scenario study is undertaken by observing the dynamic evolution behaviour of energy intensity and economic growth in reality. The concept of turning point of energy intensity in the four-dimensional dynamic system is put forward for the first time. By adjusting the correlation coefficients of the four-dimensional system, more effective methods being performed to steadily and diligently reduce energy intensity. Take for instance the situation in China, the problem of when and how to introduce carbon tax are settled within the framework of the four-dimensional dynamic system. The results show that, as the tax levy point of carbon tax grows larger, the energy intensity of the four-dimensional system could be controlled better. It is both important and necessary to note the inhibition effect of these changes on economic growth. The best time to levy carbon tax and the best tax levy point are achieved after a comprehensive analysis within the framework of the four-dimensional dynamic system. The more appropriate time carbon tax is started, the higher growth rate of carbon tax is adopted, the better corresponding policies and laws are made, the easier the carbon emissions could be controlled and the more energy intensity could be declined, so as to achieve the goal of reducing the carbon dioxide emissions and keeping proper energy intensity. Numerical simulations are carried out to demonstrate the results.

14/02970 The role of governments in renewable energy: the importance of policy consistency

White, W. *et al. Biomass and Bioenergy*, 2013, 57, 97–105.
The renewable energy sector (RES) often receives financial, institutional or educational support from the government. A significant challenge for the actors in the RES field is policy consistency. When investments are carried out, a prognosis for future policies must be made. If the future is uncertain, larger risk margins should be included in the investment appraisals. Sudden, unexpected policy changes are one type of uncertainty that makes it more difficult to attract capital. This study discusses the consequences of discontinuities in policy support using a case study approach. In Ontario, feed-in tariffs were introduced in 2009 and resulted in a large uptake in the programme. In 2010, the subsidies were drastically cut, resulting in the RES community losing confidence that the government would offer consistent support to the sector. In Norway, a large new biodiesel plant was opened by the Minister of the Environment only a few weeks before the government announced a major change in the bioenergy policy. As a result, the new plant was closed and restructured, and the investors lost nearly all of their investments. The government lost political credibility, making it difficult to raise private capital for new investments in this sector in Norway. The authors do not argue that policies should not be changed, but stress that the manner in which policies are changed plays an important role. This study shows that large, unexpected changes in policies increase uncertainty and may have a negative impact on investments.

Energy conservation

14/02971 A comprehensive assessment of the life cycle energy demand of passive houses

Stephan, A. *et al. Applied Energy*, 2013, 112, 23–34.
Certifications such as the passive house aim to reduce the final space heating energy demand of residential buildings. The latter are responsible for a significant share of final energy consumption in Europe of which nearly 70% is associated with space conditioning, notably heating. The improvement of the energy efficiency of residential buildings, in terms of space heating, can therefore reduce their total energy demand. However, most certifications totally overlook other energy requirements associated with residential buildings. Studies on passive houses do not take into consideration the embodied energy required to manufacture the building materials, especially the large amount of insulation required to achieve high operational efficiencies. At an urban scale, most passive houses are single-family detached houses located in low density suburbs with a high car usage, resulting in considerable transport related energy demand. This paper analyses the total life cycle energy demand of a typical Belgian passive house, comprising embodied, operational and transport energy. The study relies on an earlier comprehensive technique and conducts a parametric analysis as well as a comparison to alternative building types. Results show that current building energy efficiency certifications might not ensure a lower energy demand and can, paradoxically result in an increased energy consumption because of their limited scope. More comprehensive system boundaries should be used to make sure that net energy savings do occur. The embodied energy of passive houses can represent up to 77% of the total embodied and operational energy over 100 years. Also passive houses can have nearly the same energy consumption as a standard new house with the same geometry, location and number of occupants. A retrofitted apartment in the city has an energy consumption 15.2% lower than the best passive house scenario.

14/02972 A hybrid method of incorporating extended priority list into equal incremental principle for energy-saving generation dispatch of thermal power systems

Cheng, C. *et al. Energy*, 2014, 64, 688–696.

The energy-saving generation dispatch (ESGD) policy released by Chinese Government in 2007 is a new code for optimally dispatching an electric power generation portfolio in the country with the dual objectives of improving energy efficiency and reducing environmental pollution. The ESGD is substantially different from the competitive market in the developed economies, the traditional economic dispatching or the rational dispatching principle implemented in China prior to the new policy. This paper develops a hybrid method that integrates the extended priority list (EPL), the equal incremental principle (EIP) and a heuristic method to optimize daily generation schedules under ESGD. The EPL is presented to search desirable units set that satisfies the complicated duration period requirements based on thermal unit generation priority list. The EIP is developed to allocate load among the committed units within the combined set. A heuristic method is proposed to deal with inequality constraints, which usually result in difficulty for power allocation, and used to improve these results. The algorithm has been embedded into a newly developed decision support system that is currently being used by operators of the Guizhou Province power grid to make day-ahead quarter-hourly generation schedules.

14/02973 A method to determine primary energy savings of CHP plants considering plant-side and demand-side characteristics

Pohl, E. and Diarra, D. *Applied Energy*, 2014, 113, 287–293.

Cogeneration or combined heat and power (CHP) is considered as an important key technology towards efficient energy supply. While CHP is used in industrial systems for a long time, in domestic energy supply CHP technologies are penetrating recently. Domestic energy supply systems with CHP plants differ in plant- and demand-side characteristics. The effects of feed-in of CHP generated electricity is analysed in detail. This study develops an assessment method for primary energy savings by means of a primary energetic comparison of a coupled supply system with a separated supply system. The plant-side power to heat ratio and the demand-side power to heat ratio are discussed as important parameters for primary energy savings. The method leads to a theoretical potential of primary energy savings, which only depends on plant-side characteristics. The technical potential of primary energy savings is the consequence of both, plant- and demand-side, characteristics.

14/02974 A new approach to determine the outdoor temperature distributions for building energy calculations

Coskun, C. *et al. Energy Conversion and Management*, 2014, 78, 165–172.

This study formulated annual, monthly and hourly ambient temperature distributions for simplifying the calculation of cooling and heating degree-hours. In this regard, Turkey was selected as an application country, of which 79 cities were considered for modelling purposes. The temperature data over a period of 42 years were also utilized in the analysis. Similar outdoor distributions were categorized in the same group. The analysis results showed eight main annual distribution trends for the cities in Turkey. Such a detailed analysis and categorization for the outdoor temperature has been done for the first time in the literature. The outdoor temperature distributions are very useful tools for determination of heating and cooling loads while they enable the calculation of the annual-, monthly- and hourly-based degree-hours values. In this regard, a population-based outdoor temperature distribution concept was also introduced to the literature and tested for Turkey. One temperature distribution was achieved for Turkey with reference to population.

14/02975 A review of different strategies for HVAC energy saving

Vakiloroaya, V. *et al. Energy Conversion and Management*, 2014, 77, 738–754.

Decreasing the energy consumption of heating, ventilation and air conditioning (HVAC) systems is becoming increasingly important due to the rising cost of fossil fuels and environmental concerns. Therefore, finding novel ways to reduce energy consumption in buildings without compromising comfort and indoor air quality is an ongoing research challenge. One proven way of achieving energy efficiency in HVAC systems is to design systems that use novel configurations of existing system components. Each HVAC discipline has specific design requirements and each presents opportunities for energy savings. Energy efficient HVAC systems can be created by reconfiguring traditional systems to make more strategic use of existing system parts. Recent research has demonstrated that a combination of existing air-conditioning technologies can offer effective solutions for energy conservation and thermal comfort. This paper investigates and reviews the different technologies and approaches, and demonstrates their ability to improve the performance of HVAC systems in order to reduce energy consumption. For each strategy, a brief description is first presented and then by reviewing the previous studies, the influence of that method on the HVAC energy saving is investigated. Finally, a comparison study between these approaches is carried out.

14/02976 An assessment of the energy-saving potential in China's petroleum refining industry from a technical perspective

Liu, X. *et al. Energy*, 2013, 59, 38–49.

As a major contributor to productivity and employment in China, the petroleum refining industry consumes approximately 15% of industrial fuel oil and 10% of industrial coal. Given this energy-intensive characteristic, cost-effective investments for energy-efficient technologies may be a useful strategy to improve the competitiveness of China's refining industry. More importantly, this approach may alleviate the environmental problems China faces. This paper addresses the challenges posed by a highly complex refining system, incomplete industrial information, and the absence of a widely accepted evaluation method. This study models and analyses the energy-savings potential for refining and conversion processes in the context of technological change. The results indicate that upgrading process heaters have been a priority during recent years, but heat recovery and advanced process control systems will gradually begin to dominate the technological marketplace in the long term. Current technology policies will result in approximately 2.7×10^8 GJ of energy savings by 2020, keeping the average energy consumption of refineries within 57 kg oil equivalent (kgoe)/t-feed. If a cap-and-trade scheme is introduced in the future, a further reduction of up to 10% can be achieved. Various specific barriers that impede the realization of potential goals are also addressed in this study.

14/02977 An experimental investigation of energy saving potentials for room type variable-speed air conditioners in public offices: a case study from Istanbul

Yurtseven, M. B. *et al. Energy and Buildings*, 2014, 68, 165–171.

This study includes the comparison of constant speed air conditioners (non-inverter AC) and variable speed air conditioners (inverter AC) in two identical public office rooms in terms of the energy consumption by reflecting user comfort conditions as a field test. The period of this field test was in total 64 days from 31 July to 2 October 2012 and ACs were operated for 43 days intermittently. After collecting real data, total and operational energy consumptions, weighted average power and energy consumptions of the selected typical days were conducted. As can be derived from the conducted analyses, the energy saving ratio of inverter AC to non-inverter AC varies between 11% and 38%. The second important observation is that the lower cooling loads than minimum-rated power results in shifting inverter AC to on/off mode. Last but not the least, the energy efficiency ratio (EER) usually is used as an indicator for evaluating cooling efficiencies of ACs, and in this field test, although both inverter and non-inverter ACs have the similar EER values, their energy consumptions differ from each other. This results in the requirement of a new indicator for better comparison of energy efficiencies of ACs.

14/02978 Application of the combined air-conditioning systems for energy conservation in data center

Priyadumkol, J. and Kittichaikarn, C. *Energy and Buildings*, 2014, 68, 580–586.

The dissipation of heat from computer server racks is increasing. For this reason, a raised floor cooling system is important to keep the computer system operating in an effective and long-lasting manner. Thus, the proper design of an air-conditioning system in a data centre is concerned with avoiding disruptions caused by overheating. Nowadays it is not only a raised-floor cooling system that has been used in data centres but also a new cooling system called 'in-row'. This research presents a simulation of cool air flow generated by three different air-conditioning systems in data centres, which are a raised floor air-conditioning system, an in-row air-conditioning system and a combination, to give some appropriate guidelines to help designers to achieve a better and more efficient cooling system. Dimensionless parameters in the form of supply heat index, heat load of server racks and the volume flow rate from perforated tile were carried out by considering the rack inlet temperature compared with the standard air temperature of ASHRAE. The results show that these parameters provide an effective tool to the improvement of energy efficiency in data centres.

14/02979 Applying smart models for energy saving in optimal chiller loading

Chen, C.-L. *et al. Energy and Buildings*, 2014, 68, 364–371.

This study used neural networks (NN) to build models of power consumption of the chiller and particle swarm optimization (PSO) algorithm to optimize the chiller loading for minimal power consumption. The authors obtained 12.68% power saving on 55% chiller partial load rate (PLR) and 17.63% power saving on 70% PLR after analysis and comparison with the linear regression and equal loading distribution methods. Therefore, the NN PSO method solved the problem of fast convergence on optimal chiller load, and produced highly accurate results within a short timeframe. The proposed approaches can be applied to air-conditioning systems and other related optimization problems.

14/02980 Control optimizations for heat recovery from CO_2 refrigeration systems in supermarket

Ge, Y. T. and Tassou, S. A. *Energy Conversion and Management*, 2014, 78, 245–252.

A modern supermarket energy control system has a concurrent need for electricity, food refrigeration and space heating or cooling. Approximately 10% of this energy is for conventional gas-powered heating. In recent years, the use of CO_2 as a refrigerant in supermarket systems has received considerable attention due to its negligible contribution to direct greenhouse gas emissions and excellent thermophysical and heat transfer properties. CO_2 refrigeration systems also offer more compact component designs over a conventional hydrofluorocarbon system and heat recovery potential from compressor discharge. In this paper, the heat recovery potential of an all-CO_2 cascade refrigeration system in a supermarket has been investigated using the supermarket simulation model 'SuperSim' developed by the authors. It has been shown that at UK weather conditions, the heat recovery potential of CO_2 refrigeration systems can be increased by increasing the condenser/gas cooler pressure to the point where all the heat requirements are satisfied. However, the optimum level of heat recovery will vary during the year and the control system should be able to continuously optimize this level based on the relative cost of energy, i.e. gas and electricity.

14/02981 Development of the 'Home Energy Conservation Support Program' and its effects on family behavior

Shimokawa, M. and Tezuka, T. *Applied Energy*, 2014, 114, 654–662.

The Home Energy Conservation Support Program was designed to promote residential energy conservation by encouraging family communication and rivalry against other families, and to get families' energy consumption data sustainably for analysis. This paper describes the results of the programme's performance evaluation through its implementation. The programme members can obtain evaluation results about their energy consumption by inputting their monthly energy consumption data and also utilize the information obtained to save energy in the future. The estimated reduction rates in energy consumption of members suggest that the programme has prompted energy-saving behaviour among them, and that energy-saving for 'lighting and electric appliances' is harder than for 'heating'. Additionally, this programme demonstrated the possibility of sustained investigation on energy consumption characteristics.

14/02982 Energy demands and potential savings in European office buildings: case studies based on EnergyPlus simulations

Boyano, A. *et al. Energy and Buildings*, 2013, 65, 19–28.

This article presents key energy use figures and explores the energy saving potentials in office buildings across Europe by simulating several currently available scenarios. The information provided in this research work is based on a review of relevant literature and the results of EnergyPlus simulations of a reference office building that can be considered as a representative office building across Europe. Three locations were selected to represent the three climate zones in which Europe was divided. Lighting has been pointed out as an area with significant improvement potentials. These improvements have been investigated by using two scenarios with different lighting control systems. In both cases and regardless of the location of the office building, the energy savings were achieved with already existing technology and will bring important reductions in the overall energy bill. Two further aspects were investigated in this work: the first one is an improvement of the insulation of the windows and the external walls (U-value) and the second one the orientation of the building. Unlikely to the lighting improvements, the location of the buildings highly influences the amount of energy required by heating, ventilation and air-conditioning systems. It is observed that higher insulation factors are recommended in cold- and medium-climate zones while they should be carefully chosen in the warm-climate zones. Office buildings constructed in warm-climate zones are subjected to higher heat gains that cannot be easily released from buildings within a well-insulated envelope. Consequently, the energy demand for cooling purposes is increased, affecting the overall energy consumption and the economic performance of the building.

14/02983 Energy efficiency – how far can we raise the bar? Revealing the potential of best available technologies

Letschert, V. *et al. Energy*, 2013, 59, 72–82.

This paper presents the first attempt to quantify the potential impacts of a massive deployment of state-of-the-art energy-efficient technologies in the most energy-consuming economies in the world: the USA, the European Union, China, and India. The authors first identified the most efficient technologies that are currently available for a wide range of end uses in the residential and industrial sectors. The technologies selected were either engineered with the best available existing components or were the most promising emerging technologies believed to be producible on a large scale in the near future. Using a bottom-up energy model developed at Lawrence Berkeley National Laboratory, the authors modelled the most aggressive foreseeable policy that would result in making the best available technologies mandatory by 2015. They estimated that adoption of the best available technologies would avoid 2600 TWh, or about 20% of the projected energy consumption and 1.5 Gt of carbon dioxide emissions by 2030. The authors believe that this study, which brings engineering knowledge of technologies together with a rigorous energy model, is the most reliable analysis to date of the maximum potential of energy efficiency.

14/02984 Energy payback: an attributional and environmentally focused approach to energy balance in net zero energy buildings

Bourrelle, J. S. *et al. Energy and Buildings*, 2013, 65, 84–92.

Net zero-energy buildings (nZEBs) are grid-connected buildings that do not require net inputs of non-renewable energy over a defined period of their life cycle. Energy requirements of nZEBs have until now been assessed based on the impact buildings have on the existing energy system. This paper introduces a new approach to nZEB energy balance that takes into account the actual amount of energy nZEBs require. Energy balance methods previously proposed for nZEBs are illustrated in a new way and expressed in a series of equations based on a common terminology. Taking a different standpoint on the very logic that lies behind energy calculations; this article presents a new approach to energy balance in nZEBs. The paper highlights the important difference between preventing an increase in the demand for grid energy and ensuring that a building requires no net non-renewable energy. The authors argue that an energy payback approach constitutes a more adequate way to tackle the environmental challenges nZEBs are meant to help solving, and to abide to a definition which stipulates that nZEBs should require no net non-renewable energy.

14/02985 Energy refurbishment of existing buildings through the use of phase change materials: energy savings and indoor comfort in the cooling season

Ascione, F. *et al. Applied Energy*, 2014, 113, 990–1007.

With reference to building applications, recent scientific literature shows good potential in reducing cooling loads by means of phase change materials (PCMs), integrated in the building exterior envelope. This paper proposes a deepening, by investigating if these dynamic components could contribute in reducing building cooling demand in Mediterranean climates. An office building is analysed, with reference to the entire cooling season (from 1 May to 30 September), in reliable conditions as regards building use, and thus internal gains, occupancy, activation of cooling systems. In detail, through hourly energy simulation, the achievable cooling energy savings have been calculated with reference to a well-insulated massive building, refurbished by means of addition of PCM plaster on the inside of the exterior envelope. Five Mediterranean climates have been taken into account: Ankara (Turkey), Athens (Greece), Naples (Italy), Marseille (France) and Seville (Spain). The studies regarded the influences of the phase change temperature, thickness of the PCM wallboard and location of the PCM layer. Beyond the evaluation of the absolute savings of primary energy requests for cooling, the energy saving rate and the not-overheating time have been calculated, respectively, by considering an air-conditioned building and a naturally ventilated building with free-running indoor temperatures. Starting from the achieved results, through the values of the proposed indicators, this paper would suggest information useful for proper design and selection of phase change materials for building applications.

14/02986 Engineering economic assessment of whole-house residential wood heating in New York

Loughlin, D. H. and Dodder, R. S. *Biomass and Bioenergy*, 2014, 60, 79–87.

Wood devices increasingly are being used for residential space heating in New York, USA. Motivations include avoiding high and variable fuel costs, promoting energy independence, mitigating climate change and stimulating local economic development. In this study, the influence of fuel prices, device costs, and device efficiencies on heating costs was examined. Lifetime costs of alternative heating technologies were calculated for a house in Syracuse, New York. Calculations were repeated to explore discount rates and fuel price projections. Combinations of wood price and device cost and efficiency were identified at which wood is competitive with other fuels. The results suggest that fuel costs drive competitiveness more than capital and installation costs. At typical wood prices, natural gas often is the least expensive option. Many rural areas do not have access to gas, however, and high-efficiency wood-heating devices can be very competitive with heat pumps, propane boilers, and fuel-oil boilers. Availability of low-cost or on-site wood can make wood the least expensive option. However, even 'free' wood is not free when the equipment, labour, space and time required are considered. Furthermore, efficiencies of wood devices and their pollutant emissions can differ greatly. High emission rates have led to restrictions on use of specific wood-heating devices in some locations. Improved information and tools should be available to consumers for evaluating the suitability of wood heating for their particular situations. The work presented here is an example of such information.

14/02987 Experimental evaluation of a controlled hybrid two-phase multi-microchannel cooling and heat recovery system driven by liquid pump and vapor compressor

Wu, D. *et al. International Journal of Refrigeration*, 2013, 36, (2), 375–389.

The energy use in data centres is on an accelerating rise due to both demand and technological limitations. Today, the most widely used cooling strategy for data centres is refrigerated air-cooling. Unfortunately, air-cooling presents phenomenally low efficiencies. Therefore, green computing paradigms are needed to improve energy efficiency by several orders of magnitude and allow a continued chip scaling for tackling the energy crisis in future-generation data centres. A promising solution would be implementing direct on-chip two-phase cooling technology, which not only improves the heat removal efficiency but also permits the reuse of waste heat since the two-phase coolant can cool computer chips effectively at 60 °C. In this study a specific cooling cycle using micro-evaporation technology has been experimentally evaluated considering different aspects such as cooling cycle and energy recovery efficiencies and controllability. In summary, this novel cycle shows strong competence in energy usage, heat recovery and controllability towards green data centres.

14/02988 Field-based study on the energy-saving effects of CO_2 demand controlled ventilation in an office with application of energy recovery ventilators

Fan, Y. *et al. Energy and Buildings*, 2014, 68, 412–422.

Field studies were carried out to investigate the thermal performance of ceiling-based heating, ventilation and air-conditioning systems, which typically consist of package air-conditioners and an energy recovery ventilator (ERV), and to test the energy-saving efficiency of CO_2-demand controlled ventilation systems with integrated ERV systems. Measurements from sensors placed in both the occupied zone (0–1.8 m) and the upper ventilation zone (at ceiling height) were taken in an environmentally controlled, open-type office, configured with workstation furniture and partitions. The distributions of temperature, relative humidity, and CO_2 concentration were assessed throughout the test site for four scenarios. Tests were conducted to investigate the effects of the ERV, heat loss from the ducts, CO_2 demand control strategies, and contaminant patterns generated in a real office. Measurements showed that, with the application of an ERV system, the energy consumption of the air-conditioning system could be reduced by 20–30% and that of the ventilation system, i.e. outdoor air load, likewise reduced by 60–70%.

14/02989 Four E analysis and multi-objective optimization of an ice thermal energy storage for air-conditioning applications

Sanaye, S. and Shirazi, A. *International Journal of Refrigeration*, 2013, 36, (3), 828–841.

One method to reduce the peak electrical demand of air-conditioning (A/C) systems is incorporating an ice thermal energy storage (ITES) with the A/C system. In this paper, an ITES system was modelled for A/C applications and analysed from energy, exergy, economic, and environmental aspects (4E analysis). Applying the genetic algorithm optimization technique, multi-objective optimization of the system was performed and the optimum values of system design parameters were obtained. The exergy efficiency and total cost rate were considered as objective functions. The performance of modelled ITES system was also compared with a conventional system. The results indicated that electricity consumption in ITES system was 10.9% lower than that of the conventional one. Furthermore, 0.659×10^6 kg of CO_2 was prevented from emitting into the atmosphere in comparison with the conventional system. The extra capital cost associated with using ITES system was paid back with savings in electricity consumption in 3.39 years.

14/02990 Mathematical description for the measurement and verification of energy efficiency improvement

Xia, X. and Zhang, J. *Applied Energy*, 2013, 111, 247–256.

Many energy efficiency projects are initiated to reach various energy saving targets. These energy saving targets need to be measured and verified, and in many countries such a measurement and verification (M&V) activity is guided by the International Performance Measurement and Verification Protocol (IPMVP). However, M&V is widely regarded as an inaccurate science: an engineering practice relying heavily on professional judgement. This paper presents a mathematical description of the energy efficiency M&V problem and thus casts into a scientific framework the basic M&V concepts, propositions, techniques and methodologies. For this purpose, a general description of energy system modelling is provided to facilitate the discussion, strict mathematical definitions for baseline and baseline adjustment are given, and the M&V plan development is formulated as an M&V modelling problem. An optimal M&V plan is therefore obtained through solving a calculus of variation, or equivalently, an optimal control problem. This approach provides a fruitful source of research problems by which optimal M&V plans under various practical constraints can be determined. With the aid of linear control system models, this mathematical description also provides sufficient conditions for M&V practitioners to determine which one of the four M&V options in IPMVP should be used in a practical M&V project.

14/02991 Monitored lighting energy savings from dimmable lighting controls in The New York Times headquarters building

Fernandes, L. L. *et al. Energy and Buildings*, 2014, 68, 498–514.

Digital addressable, dimmable lighting controls were introduced to the US market in the early 2000s with the promise of energy savings while allowing greater flexibility than their analogue counterpart. The New York Times company installed this emerging technology, after thorough pre-procurement testing, in their new building in New York, USA. Four years after full occupancy (2007), the owner agreed to participate in post-occupancy monitoring of the lighting system to verify actual performance. Annual lighting energy savings from daylighting, setpoint tuning and occupancy controls were determined for the daylit, open-plan office areas on three typical floors (6th, 11th and 20th) of the 51-storey tower. Energy savings were calculated from data recorded by the lighting control system, after calibration through independent energy consumption measurements. Savings from dimming controls (daylighting and setpoint tuning) were 12.6 $kWh/m^2 yr$ for the daylit spaces on the three floors overall, or 20%, relative to ASHRAE 90.1–2007. Against the prescriptive code in effect at the time of the building's construction (ASHRAE 90.1–2001), savings were 21.0 $kWh/m^2 yr$ or 28%. Annual lighting energy use with all lighting control strategies was 33.9 $kWh/m^2 yr$ in the daylit, open plan zones on average for the three floors. A simple payback analysis was conducted.

14/02992 Multi-perspective analysis of China's energy supply security

Geng, J.-B. and Ji, Q. *Energy*, 2014, 64, 541–550.

China's energy supply security has faced many challenges such as the drastic change of the international energy environment and the domestic energy situation and so on. This paper constructs a multidimensional indicator system for the main risks derived from four aspects to evaluate China's energy supply security and to analyse its evolutionary characteristics from 1994 to 2011. The results indicate that the situation of China's energy supply security generally presented a downtrend during 1994–2008, as a result of increasing international energy market monopoly and high volatility of international crude oil prices. After 2008, the overall level of China's energy supply security has improved to the level of 2003, which is attributed to the relatively stable international energy environment as well as the effective implementation of energy policies.

14/02993 Network synergy effect: establishing a synergy between building network and peer network energy conservation effects

Xu, X. *et al. Energy and Buildings*, 2014, 68, 312–320.

Researchers have demonstrated that network effects on energy consumption exist when buildings are examined within physical networks (i.e. they exhibit an inter-building effects) and when individuals influence the energy use of their peers (i.e. a peer network effect is present). However, any synergy that may exist between these two effects from which greater aggregate energy savings can be achieved remains unexplored. To examine this potential synergy, the authors simulated a residential block in EnergyPlus and analysed the impact of two retrofit options. They identified a case where the less energy efficient option for a single house produced higher efficiency in the neighbouring houses. The authors then conducted a survey of homeowners that asked them to make a decision between such retrofit options. The results reveal a phenomenon that knowledge of the impact of the two retrofit options on each building combined with strong personal relationships between the homeowners can drive decision-making toward aggregate optimal outcomes. These outcomes resulted in energy savings that were greater than the sum of the energy saving potential when either one of the conditions was individually satisfied. The study concluded by defining this additional energy saving potential at the intersection between the two effects as the network synergy effect.

14/02994 On the characterization and monitoring of building energy demand using statistical process control methodologies

Braga, L. C. *et al. Energy and Buildings*, 2013, 65, 205–219.

A statistical process control-based system and scheme for monitoring, assessment and tracking of energy consumption is presented. The proposed strategy is set up using a multichannel structure to model and estimate the statistics profile (average and uncertainty) of the energy consumption of a building during a predetermined cycle, e.g. a week period. The statistics profile is analysed with statistical process control techniques for signalling alarms or reporting interpreted faults of unpredicted or unusual behaviour of energy demand. Identification of deviations from predicted or programmed consumption profiles modelled by a multichannel structure are shown to be easily designed, tuned and implemented with low computation demand of memory and processing speed. Simulated results illustrate the multichannel structure programing and parameters tuning. Experimental results are presented to exemplify the proposed strategy.

14/02995 Optimisation of the energy efficiency of bread-baking ovens using a combined experimental and computational approach

Khatir, Z. *et al. Applied Energy*, 2013, 112, 918–927.

Changing legislation and rising energy costs are bringing the need for efficient baking processes into much sharper focus. High-speed air impingement bread-baking ovens are complex systems using air flow to transfer heat to the product. In this paper, computational fluid dynamics (CFD) is combined with experimental analysis to develop a rigorous scientific framework for the rapid generation of forced convection oven designs. A design parameterization of a three-dimensional generic oven model is carried out for a wide range of oven sizes and flow conditions to optimize desirable features such as temperature uniformity throughout the oven, energy efficiency and manufacturability. Coupled with the computational model, a series of experiments measuring the local convective heat transfer coefficient (h_c) are undertaken. The facility used for the heat transfer experiments is representative of a scaled-down production oven where the air temperature and velocity as well as important physical constraints such as nozzle dimensions and nozzle-to-surface distance can be varied. An efficient energy model is developed using a CFD analysis calibrated using experimentally determined inputs. Results from a range of oven designs are presented together with ensuing energy usage and savings.

14/02996 Potential for energy cost savings by utilising alternative temperature control strategies for controlled atmosphere stored apples

East, A. R. *et al. International Journal of Refrigeration*, 2013, 36, (3), 1109–1117.

Optimal storage conditions for apples are usually defined as those that maximize possible storage duration, but could be redefined as those conditions that result in sufficient preservation while minimizing energy costs. A review of research on controlled atmosphere (CA) storage suggests that temperature changes in CA have less impact on product deterioration than in air. This paper reviews the underpinning observations of fruit physiology in CA and the possible approaches to reducing energy costs through temperature manipulation. Experimental results indicate that minor increases in temperature during CA storage have little influence on apple quality outcomes across a number of apple cultivars. Calculations for applying a 9 h on, 15 h off cycle estimated an approximate 40% of electricity cost savings while only incurring a 0.5 °C average fruit temperature swing. These results suggest that opportunities for substantial energy cost savings in controlled atmosphere apple stores exist.

14/02997 Productivity trends of Chinese regions: a perspective from energy saving and environmental regulations

Yang, F. *et al. Applied Energy*, 2013, 110, 82–89.

Energy saving and emissions reduction has recalibrated China's economic development mode to a more sustainable way. In this study, the authors constructed a novel total factor productivity (TFP) index using a sub-vector enhanced hyperbolic distance function, which simultaneously credits for an expansion in economic output along with contractions in energy input and undesirable output. This index was then employed to evaluate the TFP change for 30 provincial regions in China during 2006–2015. The results indicate that China's productivity considering energy saving and emissions reduction experiences a gradual improvement shifting from decline to increase throughout this decade, and the amelioration can mainly be attributed to the efficiency improvements from the east regions, while the contributions from technical change component will not emerge until 2013 due to insufficient energy and environmental R&D investments. Finally, some policy recommendations are also put forward on how to enhance China's productivity.

14/02998 Specification requirements for inter-seasonal heat storage systems in a low energy residential house

Gondre, D. *et al. Energy Conversion and Management*, 2014, 77, 628–636.

This paper aims at providing sizing information concerning a thermal storage system in the case of a low-energy consumption building ($<50\,\mathrm{kW\,h/m^2\,y}$). Numerical simulations for a reference individual building were run for 23 different cities in Europe. Results show a clear correlation between annual heat demand Q_y and annual heating degree-day (HDD): $Q_y = f_1(HDD)$. There is also a good correlation between power demand and heating degree days (HDD). But as heat coverage of the entire heating period may be too ambitious, the analysis goes further. It presents a correlation between heating demand Q and HDD as a function of the storage system autonomy t of the form $Q = (1 - \exp(-t/\tau)) \times Q_y$ with $\tau = f_2(HDD)$. It also gives the absolute distribution of sorted power demand values as a function of HDD in the form of a power sizing chart. The purpose of this chart is to provide specifications for the sizing of a thermal storage system intended to partially cover energy needs and power demand of a low-energy residential house.

14/02999 Standards and labeling program for refrigerators: comparing India with others

Chunekar, A. *Energy Policy*, 2014, 65, 626–630.

Energy efficiency levels for the 'Standards and Labeling' (S&L) programme in India for frost-free refrigerators are compared with similar programmes in China, the USA and European Union. A normalization method developed by the International Energy Agency is adopted with India as a benchmark for comparison. It is observed that the energy consumption level corresponding to minimum energy performance standard (MEPS) is very high in India. India also lags behind other countries on the consumption level corresponding to highest efficiency rating. Also, the range of consumption levels corresponding to a label is wide which dilutes the efficacy of label. India has aggressively proposed to tighten the ratings for frost-free refrigerators in 2014 by 36% across all the bands. This measure will make its highest efficiency rating comparable to other countries. However, due to the wide gap in the consumption levels across the ratings, the revised MEPS will still lag behind other countries. One possible outcome of high MEPS is that as the ratings are tightened, the market may move to lower-rated models significantly undermining the tightening effect.

14/03000 Standby electricity consumption and saving potentials of Turkish households

Sahin, M. C. and Koksal, M. A. *Applied Energy*, 2014, 114, 531–538.

The share of the residential sector currently accounts for about 25% of the national electricity consumption in Turkey. Due to increase in household income levels and decrease in the costs of appliances; significant increases in appliance ownerships and residential electricity consumption levels have been observed in recent years. Most domestic appliances continue consuming electricity when they are not performing their primary functions, i.e. at standby mode, which can constitute up 15% of the total household electricity consumption in some countries. Although the demand in Turkish residential electricity consumption is increasing, there are limited studies on the components of the residential electricity consumption and no studies specifically examining the extent and effects of standby electricity consumption using a surveying/measurement methodology. Thus, determining the share of standby electricity consumption in total home electricity use and the ways of reducing it are important issues in residential energy conservation strategies. In this study, surveys and standby power measurements are conducted at 260 households in Ankara, Turkey, to determine the amount, share and saving potentials of the standby electricity consumption of Turkish homes. The survey is designed to gather information on the appliance properties, lights, electricity consumption behaviour, economic and demographics of the occupants, and electricity bills. A total of 1746 appliances with standby power are measured in the surveyed homes. Using the survey and standby power measurements data, the standby, active and lighting end-use electricity consumptions of the surveyed homes are determined. The average Turkish household standby power and standby electricity consumption are estimated as 22 W and 95 kW h/yr, respectively. It was also found that the standby electricity consumption constitutes 4% of the total electricity consumption in Turkish homes. Two scenarios are then applied to the surveyed homes to determine the potentials in reducing standby electricity consumption of the households.

14/03001 The influence of an estimated energy saving due to natural ventilation on the Mexican energy system

Oropeza-Perez, I. and Østergaard, P. A. *Energy*, 2014, 64, 1080–1091.

This article shows the impacts of the extensive use of natural ventilation in the Mexican residential sector on the Mexican energy system. By integrating a thermal-airflow simulation programme with an energy systems analysis model, the impact on the Mexican energy system of replacing air conditioning, in particular, with natural ventilation to cool residential buildings is determined. It is shown that when, as in Mexico, there is a relatively simple connection between supply and electricity demand, natural ventilation creates savings which could be used to reduce either the fossil-fuel-based generation and mitigate CO_2 emissions, or the use of water reservoirs and hydrogeneration during a dry season.

14/03002 The use of variable speed drives for cost-effective energy savings in South African mine cooling systems

Du Plessis, G. E. *et al. Applied Energy*, 2013, 111, 16–27.

An industrial energy efficiency improvement through the introduction of modern technology is an important demand-side management initiative. Cooling systems on South African mines have been identified as large electricity consumers. There is significant potential for energy efficiency improvement by the widespread introduction of variable speed drive (VSD) technology. An energy audit was conducted on 20 large mine cooling systems and potential savings and feasibility indicators were calculated. A pilot implementation study was also done on one mine to experimentally validate the estimated savings. In this paper, the results of the audit, the potential savings and the pilot study results are presented. It is shown that large-scale implementation of VSDs on mine cooling system pumps and fans is economically viable. A total annual electrical energy saving of 144,721 MW h, or 32.2%, can be achieved. An annual cost saving of US\$6,938,148 and CO_2 emissions reduction of 132 Mton is possible. The implementation of VSDs on mine chiller compressors will also result in large energy savings, but is not economically feasible at present. Results of the pilot study indicate an electricity savings of 29.9%. The results are important to decision makers and indicate the significant impact that widespread VSD usage on mine cooling systems can have on South African mine sustainability.

14/03003 Thermal transmittance of window systems and effects on building heating energy use and energy efficiency ratings in South Korea

Yoo, S. *et al. Energy and Buildings*, 2013, 67, 236–244.

Since the ratification of the Kyoto Protocol, governments around the world have announced energy policies to reduce energy use and greenhouse gas emissions. The construction sector accounts for approximately 40% of global energy use. Therefore, technological as well as political means have been employed to realize a reduction in energy consumption in this sector. High-efficiency window systems can play an important role in reducing energy consumption in buildings. The authors measured the thermal performance (*U*-factor) of different window systems and analysed their effects on energy savings. All systems considered in this study helped improve insulating performance. The results showed that the use of temperable, low-e glazed units helped achieve 19.9%, 17.1%, and 15.2% energy savings in the study areas in the central and southern regions in South Korea and in Jeju Island, respectively. Despite the great potential for energy savings in the central region, only half the buildings qualified for Rating 2 certification, whereas all buildings on Jeju Island qualify for the most energy efficient rating. This suggests that the energy efficiency ratings for buildings in South Korea are being applied to these three regions according to the regional building codes and climatic conditions.

17 ENERGY CONVERSION AND RECYCLING

14/03004 A comparative study on various turbocharging approaches based on IC engine exhaust gas energy recovery

Fu, J. *et al. Applied Energy*, 2014, 113, 248–257.

In this paper, two kinds of novel boosting pressure approaches, steam turbocharging and steam-assisted turbocharging, have been proposed. And both are based on the principle of internal combustion (IC) engine exhaust gas energy recovery. In order to demonstrate the advantages of the two types of new turbocharging concepts, a comparative study among exhaust turbocharging, steam turbocharging and steam-assisted turbocharging was conducted on a passenger car gasoline engine, and the effects of various boosting pressure approaches on IC engine performances as well as turbocharging system energy flow were analysed. The results show that, steam turbocharging can achieve the target intake pressure in the entire IC engine speed range, while steam-assisted turbocharging can improve IC engine intake pressure at the low-speed operating conditions; the energy saving potentials from high to low follow the subsequence of steam turbocharging, steam-assisted turbocharging and exhaust turbocharging; with the increasing of IC engine speed, the exhaust gas energy recovery efficiency of steam turbocharging system decreases and its maximum value is 6.5%, while the exhaust gas energy recovery efficiency of steam-assisted turbocharging and exhaust turbocharging first increases and then decreases.

14/03005 Anaerobic digestion of peel waste and wastewater for on site energy generation in a citrus processing facility

Koppar, A. and Pullammanappallil, P. *Energy*, 2013, 60, 62–68.

A citrus-processing facility produces significant quantities of both peel waste and wastewater. A leach–bed batch anaerobic digester was operated successfully at thermophilic (55 °C) temperature for biogasification of citrus peel waste. The retention time in the digester was 25 days. The citrus processing wastewater was digested in a thermophilic down flow stationary fixed film anaerobic reactor fed continuously and operated for 76 days. At an average organic loading rate of $0.51\,\mathrm{kg\,sCOD\,m^{-3}\,d^{-1}}$ the hydraulic retention time was 16 days. No long-term toxicity issues due to limonene were observed during digestion of both citrus waste feedstocks. Biogasification yielded, $0.116\,\mathrm{m^3}$ methane at $\mathrm{STP\,kg^{-1}}$ peel waste received and $2.1\,\mathrm{m^3}$ at $\mathrm{STP\,m^{-3}}$ wastewater received. An energy analysis showed that in a citrus processing plant handling 600 tons per day of fruits, the biogas produced from the waste streams is more than sufficient to meet all the electricity and fuel demands. Excess electricity generated from biogas may be sold generating estimated revenues of more than a \$1 million annually (at electricity sale price of \$0.04/kWh$_e$).

14/03006 Cooling energy efficiency and classroom air environment of a school building operated by the heat recovery air conditioning unit

Wang, Y. *et al. Energy*, 2014, 64, 991–1001.

A recently built school building has adopted a novel heat recovery ventilator and air-conditioning system. Heat recovery efficiency of the heat recovery facility and energy conservation ratio of the air-conditioning unit were analytically modelled, taking the ventilation networks into account. Following that, school classroom displacement ventilation and its thermal stratification and indoor air quality indicated by the CO_2 concentration have been numerically modelled concerning the effects of delivering ventilation flow rate and supplying air temperature. Numerical results indicate that the promotion of mechanical ventilation rate can simultaneously boost the dilution of indoor air pollutants and the non-uniformity of indoor thermal and pollutant distributions. Subsequent energy performance analysis demonstrates that classroom energy demands for ventilation and cooling could be reduced with the promotion of heat recovery efficiency of the ventilation facility, and the energy conservation ratio of the air-conditioning unit decreases with the increasing temperatures of supplying air. Fitting correlations of heat recovery ventilation and cooling energy conservation have been presented.

14/03007 Dynamic behavior of Rankine cycle system for waste heat recovery of heavy duty diesel engines under driving cycle

Xie, H. and Yang, C. *Applied Energy*, 2013, 112, 130–141.

The Rankine cycle system (RCS) used to recover the waste heat energy (WHE) from engines has been regarded as one of the potential ways of achieving higher efficiency. However, it is of great challenge to keep the RCS performing well under the driving cycle. This paper tries to explain the RCS's on-road inefficiency. The operating process of the RCS under the driving cycle was analysed in advance. Afterwards, four basic operating modes were defined: start-up mode, turbine turning mode, power mode and protection mode. Then, a RCS model was established and operating performances of the RCS under an actual driving cycle were discussed based on this model. The results indicate that the on-road Rankine cycle system efficiency (RCS-E) is as low as 3.63%, which is less than half of the design RCS-E (7.77%) at the rated operating point. Despite the inevitable vapour state fluctuation, it is the operating mode switching during the driving cycle that leads to the on-road inefficiency. Further investigations indicate that the expander safety temperature and its safety margin affected by the working fluids, designed superheat degree and evaporating pressure are the main factors determining the operating mode switching. Finally, the effects of the working fluids, designed superheat degree and evaporating pressure on the operating mode switching and Rankine cycle efficiencies were profoundly investigated. The study shows that the dry and isentropic fluids are superior to the wet ones due to their less probabilities of droplets formation as a consequence of their saturated vapour characteristics. The effects of the vapour parameters on the RCT-E and operating mode switching are opposite. Therefore, in order to optimize the RCS, it would be better to take full consideration in reducing the operating mode switching, while pursuing the maximum RCT-E.

14/03008 Early development of an energy recovery wind turbine generator for exhaust air system

Chong, W. T. *et al. Applied Energy*, 2013, 112, 568–575.

An innovative idea on extracting clean energy from wind resources with a micro wind turbine system for power generation is introduced in this paper. This system generates on-site clean energy using a micro wind generation system. A vertical axis wind turbine (VAWT) with an enclosure is mounted above a cooling tower's exhaust fan to harness the wind energy for producing electricity. The VAWT is positioned at a specific position at the cooling tower outlet to avoid a negative impact on the performance of the cooling tower. The enclosure can act as a safety cover and also enhance the performance of the VAWT. It is designed with several guide-vanes positioned at the up-stream side of the wind turbine to create a Venturi effect and guide the wind before it interacts with the turbine blades. Moreover, the enclosure design is comprised of diffuser-plates that can draw more wind and accelerate the flow. Laboratory tests conducted on a scaled model show no measurable difference in the air intake speed and current consumption of the power-driven fan when the turbine was spinning above the cooling tower. Field test on an actual induced-draft cooling tower shows no significant difference on the outlet air speed of the cooling tower. A small difference was observed on the power consumption by the fan motor, which is 0.39% higher with the presence of the VAWT. This system is retrofit-able to existing cooling towers and has very high market potential due to abundant cooling towers and other unnatural exhaust air resources globally.

14/03009 Electricity and substitute natural gas generation from the conversion of wastewater treatment plant sludge

Bidart, C. *et al. Applied Energy*, 2014, 113, 404–413.

In Chile, the energy that can potentially be obtained from the digestion of sludge generated from wastewater treatment processing (WwT) was calculated using a holistic approach. The different pathways of electricity generation via the direct combustion of biogas and upgraded biogas produced as bio-substitute natural gas (Bio-SNG) for injection into the gas grid were assessed and compared. Information such as the served population, WwT technology employed and geographical distribution of the sludge sources was gathered to estimate energy potential. Additionally, technical and economic information was collected from the literature. Furthermore, economic modelling was used to compare the two end-use alternatives. The results were presented by using supply-cost curves and then integrated into a geographical information system, the latter shows the distribution of the energy potential nationally. A comparison with a reference market price of the corresponding secondary energy type, electricity or natural gas, was conducted to elucidate the economic attractiveness of the two assessed options. From the assessment, it was concluded that the economic potential for the injection of Bio-SNG into the grid is $19\,\mathrm{MM\,N\,m^3\,y^{-1}}$ at a representative generation cost of approximately $43\,€\,\mathrm{MMBTU^{-1}}$, whereas biogas for the electricity generation pathway has an economic potential of $75\,\mathrm{GW\,h_e\,y^{-1}}$ at a representative generation cost of $21.5\,\mathrm{ct€\,kWh_e^{-1}}$. In view of these results, it can be observed that the electricity generation pathway may offer more major economic and environmental benefits than the Bio-SNG pathway, despite both options being hardly competitive without subsidies. Additionally, it can be observed that the Bio-SNG route is not competitive in most cases, and it is economically attractive solely under restricted conditions, principally those established by plant capacity. Furthermore, steadily increasing electricity prices over time suggests that the biogas-to-electricity option will become progressively more competitive. These results can be considered as outcomes to elaborate a national macro-policy to tackle the sludge issue under a waste-to-energy approach.

14/03010 Evaluation of options for energy recovery from municipal solid waste in India using the hierarchical analytical network process

Nixon, J. D. *et al. Energy*, 2013, 59, 215–223.

In this paper a hierarchical analytical network process (HANP) model is demonstrated for evaluating alternative technologies for generating electricity from municipal solid waste (MSW) in India. The technological alternatives and evaluation criteria for the HANP study are characterized by reviewing the literature and consulting experts in the field of waste management. Technologies reviewed in the context of India include landfill, anaerobic digestion, incineration, pelletization and gasification. To investigate the sensitivity of the result, the authors examined variations in expert opinions and carried out an analytical hierarchy process (AHP) analysis for comparison. They found that anaerobic digestion is the preferred technology for generating electricity from MSW in India. Gasification is indicated as the preferred technology in an AHP model due to the exclusion of criteria dependencies and in an HANP analysis when placing a high priority on net output and retention time. The authors concluded that HANP successfully provides a structured framework for recommending which technologies to pursue in India, and the adoption of such tools is critical at a time when key investments in infrastructure are being made. Therefore the presented methodology is thought to have a wider potential for investors, policy makers, researchers and plant developers in India and elsewhere.

14/03011 Feasibility assessment of refinery waste heat-to-power conversion using an organic Rankine cycle

Jung, H. C. *et al. Energy Conversion and Management*, 2014, 77, 396–407.

Industrial waste heat is a large potential resource for generation of carbon-free electricity. This study investigates the technical and economic feasibility of converting waste heat from a stream of liquid kerosene which must be cooled down to control the vacuum distillation temperature. The process conditions were determined for a simple 250 kW organic Rankine cycle (ORC) with a heat extraction loop. The pinch point technique was adopted to determine the optimum evaporation and condensation temperatures and assess the influence of the kerosene temperature at the evaporator exit on net power output. The operating conditions and performance of the ORC system were evaluated with eight potential refrigerants and refrigerant mixtures such as R123, R134a, R245fa, isobutane, butane, pentane, an equimolar mixture of butane and pentane, and a mixture of 40% isobutane and 50% butane on a mole basis. A financial model was established for the total plant cost. Results show that isobutane, of the pure fluids, yields the best plant efficiency of 6.8% with approximately half of the kerosene flow available, and the efficiency can be increased up to 7.6% using the butane/pentane mixture. The optimum kerosene temperature at the evaporator outlet is estimated to be 70 °C for all the fluid, except the butane/pentane mixture, which meets the design constraint not to disturb the existing distillation process. A capital cost target of $3000/kW could be achieved with a payback period of 6.8 years and the internal rate of return of 21.8%. Therefore, if the detailed engineering, component fabrication and construction can be achieved within the cost target, the installation of a 250 kW ORC waste heat power converter on the kerosene cooling line would be technically feasible and economically viable.

14/03012 Heat recovery with heat pumps in non-energy intensive industry: a detailed bottom-up model analysis in the French food & drink industry

Seck, G. S. *et al. Applied Energy*, 2013, 111, 489–504.

Rising energy prices and environmental concerns inevitably encourages industry to get involved in promoting energy efficiency and emissions reductions. To achieve this goal, the authors have developed a detailed bottom-up energy model for a non-energy intensive industry (NEI) to study its global energy efficiency and the potential for CO_2 emissions reduction at a four-digit level of the European Union's 'Nomenclature statistique des activités économiques dans la Communauté européenne' (NACE) classification. The latter, which is generally neglected in energy analyses, is expected to play an important role in reducing industry energy intensity in the long term due to its economic and energy significance and relatively high growth rate. In this paper, the modelling of NEI is done by energy end-use owing to the unsuitability of the end-product/process approach used in the energy intensive industry modelling. As an example, the authors analysed the impact of heat recovery with heat pumps (HP) on industrial processes up to 2020 on energy savings and CO_2 emissions reductions in the French food and drink industry (F&D), the biggest NEI sector. The results showed HP could be an excellent and very promising energy recovery technology. For further detailed analysis, the depiction of HP investment cost payments is given per temperature range for each F&D subsector. This model constitutes a useful decision-making tool for assessing potential energy savings from investing in efficient technologies at the highest level of disaggregation, as well as a better subsectoral screening.

14/03013 Improved heat storage rate for an automobile coolant waste heat recovery system using phase-change material in a fin–tube heat exchanger

Shon, J. *et al. Applied Energy*, 2014, 113, 680–689.

In this study, the actual heat transfer coefficient of a phase-change material (PCM) was measured experimentally with the purpose of improving the heat storage rate of an automotive coolant waste heat storage system using the latent heat of the PCM. The heat transfer rate and time required to store heat was theoretically analysed in the system where engine coolant was heated by a fin–tube heat exchanger filled with solid PCM. The amount of heat storage necessary for sufficient heating of vehicle coolant was calculated, and the appropriate amount of PCM was determined accordingly. Based on these data, a heat exchanger capable of storing heat under the lowest possible influence of natural convection and conduction thermal resistance of the PCM was designed, and its estimated heat storage rate was calculated. The authors identified the most effective methods to improve the heat storage rate and efficiency of the PCM-filled heat exchanger.

14/03014 Improved production of short-chain fatty acids from waste activated sludge driven by carbohydrate addition in continuous-flow reactors: influence of SRT and temperature

Luo, J. *et al. Applied Energy*, 2014, 113, 51–58.

During anaerobic fermentation of waste activated sludge (WAS), the production of short-chain fatty acids (SCFAs), especially propionic acid which is considered as the most preferred carbon source for enhanced biological phosphorus removal, can be improved by controlling the suitable mass ratio of carbon to nitrogen (C/N) and pH in batch mode. In this study the influences of solids retention time (SRT) and temperature on WAS hydrolysis and acidification in the continuous-flow systems in which the C/N ratio of WAS was modified by carbohydrate addition were investigated. Experimental results showed that the increase of SRT and temperature in a pertinent range benefited the hydrolysis of fermentation substrates and the accumulation of SCFAs, and SRT 8 d and temperature 37 °C were the most preferred conditions for the production of SCFAs, especially propionic acid. As there were more consumption of protein and carbohydrate and less production of methane at SRT 8 d and temperature 37 °C, more SCFAs were accumulated. Also, both the activities of key hydrolases and acid-forming enzymes and the ratio of acidogenic bacteria to methanogens showed good agreements with SCFAs production.

14/03015 Liquefaction of waste tires by pyrolysis for oil and chemicals – a review

Quek, A. and Balasubramanian, R. *Journal of Analytical and Applied Pyrolysis*, 2013, 101, 1–16.

This article provides a critical review of past efforts over the last four decades in oil and liquids production from the pyrolysis of waste tyres. Experimental laboratory-scale and pilot-scale results from the pyrolysis of scrap tyres are included here. The various operating conditions under which pyrolysis of waste tyres is carried out are reviewed. In addition to reactor conditions such as temperature and heating rates, other aspects of the tyre pyrolysis such as catalyst type, catalyst preparation and their effects on oil yields are also reviewed. Pyrolytic oil characteristics such as heating value, sulfur content and density are summarized. The various issues with production of oil from tyre pyrolysis such as sulfur content, gaseous combustion emissions, naphtha composition are also discussed in the review. Various methods for the analysis of the pyrolytic oil composition and its refining to produce valuable products are evaluated. The review revealed that the pyrolytic oil could yield useful chemicals such as the aromatic benzene and limonene, in addition to fuel applications, depending on the type of waste tyres pyrolysed and the operating conditions of the pyrolysis process.

14/03016 Passive energy recovery from natural ventilation air streams

Hughes, B. R. *et al. Applied Energy*, 2014, 113, 127–140.

Increasing levels of urbanization and indoor air quality have led to enhanced research and development of sustainable technologies in buildings. This study investigated natural ventilation streams typically found in domestic buildings and used heat pipe technology to recover the energy from them. A computational fluid dynamics-based numerical code was used to predict the rate of heat transfer from a heat pipe heat exchanger model. The present numerical code was successfully validated against experimental data from literature. Pure water as a natural phase change material was employed to investigate the overall effectiveness of the heat pipe heat exchanger. Six models with varying vertical heights between the pipes were developed in order to investigate the optimum column pitch. A good correlation between the computational and analytical results was observed. The work focused on the vertical column height between the heat pipes and its impact on the overall rate of heat transfer, depicting an inverse relationship between the two parameters. The findings demonstrated the prospect for pre-cooling by 15.6 °C and that a recovery of 3.3 °C using this system which would assist in reducing energy consumption loads from the heating, ventilation and cooling sector, offering significant reduction in the carbon footprint of domestic buildings.

14/03017 Power generation using waste heat recovery by organic Rankine cycle in oil and gas sector in Egypt: a case study

Khatita, M. A. *et al. Energy*, 2014, 64, 462–472.

The organic Rankine cycle (ORC) is a promising technology for the conversion of heat into useful work. This study utilizes the ORC in an existing gas treatment plant in Egypt, as a case study, to recover the waste heat and convert it into electricity. A simulation model using Aspen HYSYS v7.1 has been developed for the case study. Two different cycles, the basic and the regenerative cycles, have been studied. Various working fluids have been investigated using different parameters such as net work produced, efficiency, volumetric flow rate and the irreversibility. To be more confident about the best working fluid, a capital cost and profitability analysis has been performed for the two most promising working fluids. The simulation has shown that the regenerative cycle using either benzene or cyclohexane is the most promising choice. However, the capital cost and profitability study has shown that benzene is better suited as a working fluid than cyclohexane. Finally, an optimization study on the parameters indicates that the turbo expander inlet pressure of 4.1 MPa and temperature of 290–300 °C are the most appropriate working conditions.

14/03018 Prediction of dynamic Rankine cycle waste heat recovery performance and fuel saving potential in passenger car applications considering interactions with vehicles' energy management

Horst, T. A. *et al. Energy Conversion and Management*, 2014, 78, 438–451.

Waste heat recovery (WHR) by means of a Rankine cycle is a promising approach for achieving reductions in fuel consumption and, as a result, exhaust emissions of passenger car engines. To find the best compromise between complexity and fuel-saving potential, methods for predicting the WHR performance for different system configurations and stationary, as well as dynamic driving, scenarios are needed. Since WHR systems are usually not included in today's car concepts, they are mostly designed as add-ons. As a result, their integration may lead to negative interactions due to increased vehicle weight, engine backpressure and cooling demand. These effects have to be considered when evaluating the fuel-saving potential. A new approach for predicting WHR performance and fuel-saving potential was developed and is presented here. It is based on simple dynamic models of a system for recovering exhaust gas waste heat and its interfaces with the vehicle: the exhaust system for heat input, the on-board electric system for power delivery and the engine cooling system for heat rejection. The models are validated with test bench measurements of the cycle components. A study of fuel-saving potential in an exemplary dynamic motorway driving scenario shows the effect of vehicle integration: while the WHR system could improve fuel economy by 3.4%, restrictions in power output due to the architecture of the on-board electric system, package considerations, increased weight, cooling demand and exhaust gas backpressure lead to a reduction of fuel-saving potential by 60% to 1.3%. A parameter study reveals that, in addition to weight reduction and efficiency optimization, combining the WHR system with enhanced electrification of engine peripherals is the most effective approach to improve the fuel-saving potential. When assuming an increase in power demand of the on-board electric system from 750 to 1500 W, a fuel-saving potential of 4% – referring to a 3.6% higher reference fuel consumption – is reached. WHR could therefore play an important role to overcome the challenges of increased electric power demand in future vehicles.

14/03019 Purification of used eutectic (LiCl–KCl) salt electrolyte from pyroprocessing

Cho, Y.-Z. *et al. Journal of Nuclear Materials*, 2013, 437, (1–3), 47–54.

The separation characteristics of surrogate rare-earth fission products in a eutectic (LiCl–KCl) molten salt were investigated. This system is based on the eutectic salt used for the pyroprocessing treatment of used nuclear fuel. The investigation was performed using an integrated rare-earth separation apparatus comprising a precipitation reactor, a solid detachment device, and a layer separation device. To separate rare-earth fission products, a phosphate precipitation method using both $\mathrm{Li_3PO_4}$ and $\mathrm{K_3PO_4}$ as a precipitant was performed. The use of an equivalent phosphate precipitant composed of 0.408 molar ratio-$\mathrm{K_3PO_4}$ and 0.592 molar ratio-$\mathrm{Li_3PO_4}$ can preserve the original eutectic ratio, LiCl-0.592 molar ratio (or 45.2 wt%), as well as provide a high separation efficiency of over 99.5% under conditions of 550 °C and Ar sparging when using La, Nd, Ce, and Pr chlorides. The mixture of La, Nd, Ce, and Pr phosphate had a typical monoclinic (or monazite) structure, which has been proposed as a reliable host matrix for the permanent disposal of a high-level waste form. To maximize the reusability of purified eutectic waste salt after rare-earth separation, the successive rare-earth separation process, which uses both phosphate precipitation and an oxygen sparging method, were introduced and tested with eight rare-earth (Y, La, Ce, Pr, Nd, Sm, Eu and Gd) chlorides. In the successive rare-earth separation process, the phosphate reaction was terminated within 1 h at 550 °C, and a 4–8 h oxygen sparging time were required to obtain over a 99% separation efficiency at 700–750 °C. The mixture of rare-earth precipitates separated by the successive rare-earth separation process was found to be phosphate, oxychloride, and oxide. Through the successive rare-earth separation process, the eutectic ratio of purified salt maintained its original value, and impurity content including the residual precipitant of purified salt can be minimized.

14/03020 Synthesis and performance of $\mathrm{Li[(Ni_{1/3}Co_{1/3}Mn_{1/3})_{1-x}Mg_x]O_2}$ prepared from spent lithium ion batteries

Weng, Y. *et al. Journal of Hazardous Materials*, 2013, 246–247, 163–172.

To reduce cost and secondary pollution of spent lithium ion battery (LIB) recycling caused by complicated separation and purification, a novel simplified recycling process is investigated in this paper. Removal of magnesium is a common issue in hydrometallurgy process. Considering magnesium as an important additive in LIB modification, tolerant level of magnesium in leachate is explored as well. Based on the novel recycling technology, $Li[(Ni_{1/3}Co_{1/3}Mn_{1/3})_{1-x}Mg_x]O_2$ ($0 \le x \le 0.05$) cathode materials are achieved from spent LIB. Tests of X-ray diffraction, scanning electron microscopy, thermogravimetric differential thermal analysis and so on are carried out to evaluate material properties. Electrochemical test shows an initial charge and discharge capacity of the regenerated $LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ to be 175.4 mAh g^{-1} and 152.7 mAh g^{-1} (2.7–4.3 V, 0.2 C), respectively. The capacity remains 94% of the original value after 50 cycles (2.7–4.3 V, 1 C). Results indicate that presence of magnesium up to $x = 0.01$ has no significant impact on overall performance of $Li[(Ni_{1/3}Co_{1/3}Mn_{1/3})_{1-x}Mg_x]O_2$. As a result, magnesium level as high as 360 mg L^{-1} in leachate remains tolerable. Compared with conventional limitation of magnesium content, the elimination level of magnesium exceeded general impurity-removal requirement.

14/03021 System analysis and optimisation of a Kalina split-cycle for waste heat recovery on large marine diesel engines

Larsen, U. *et al. Energy*, 2014, 64, 484–494.

Waste heat recovery systems can produce power from heat without using fuel or emitting CO_2, therefore their implementation is becoming increasingly relevant. The Kalina cycle is proposed as an efficient process for this purpose. The main reason for its high efficiency is the non-isothermal phase change characteristics of the ammonia–water working fluid. The present study investigates a unique type of Kalina process called the split-cycle, applied to the exhaust heat recovery from large marine engines. In the split-cycle, the working fluid concentration can be changed during the evaporation process in order to improve the match between the heat source and working fluid temperatures. The authors present a system analysis to identify the governing mechanisms of the process, including a comparison of the efficiency of the split-cycle and a conventional Kalina cycle and an investigation of the effects of using reheat in both cases. Results of a multivariable optimization effort using a genetic algorithm suggest that the split-cycle process can obtain a thermal efficiency of 23.2% when using reheat compared to 20.8% for a conventional reference Kalina cycle. Reheat can increase the thermal efficiency by 3.4–5.9%. A simplified cost analysis suggests higher purchase costs as result of increased process complexity.

14/03022 Techno-economic analysis and optimization of the heat recovery of utility boiler flue gas

Xu, G. *et al. Applied Energy*, 2013, 112, 907–917.

Coal-fired power plants in China consume nearly half of available coals, and the resulting CO_2 emissions cover over 40% of total national emissions. Therefore, reducing the energy expenditure of coal-fired power plants is of great significance to China's energy security and greenhouse gas reduction programmes. For coal-fired power plants, the temperature of a boiler's exhaust gas reaches 120–150 °C or even higher. The thermal energy of boiler's exhaust accounts for approximately 3–8% of the total energy of fuel input. Given these factors, the authors conducted a techno-economic analysis and optimization design of the heat recovery system using boiler exhaust gas. This research is conformed to the principles of thermodynamic, heat transfer, and hydrodynamics. Based on the data from an existing 1000 MW typical power generation unit in China, four typical flue gas heat recovery schemes are quantitatively analysed from the thermodynamics perspective. The impacts of flue gas heat recovery on net work output and standard coal consumption rate of various schemes are performed. Furthermore, the transfer area of heat recovery exchanger and the draft fan work increment due to the flue gas pressure drop are analysed. Finally, a techno-economic analysis of the heat recovery schemes is conducted, and some recommendations on optimization design parameters are proposed, with full consideration of various factors such as the decrease on fuel cost due to energy conservation as well as the investment cost of heat recovery retrofitting. The results revealed that, high-stage steam substitute scheme of flue gas heat recovery in power plant can obtain higher energy-saving effects than that of low-stage steam substitute scheme. And the energy-saving benefit of flue gas heat recovery, especially with high-stage steam substitute scheme, is weakened by large heat exchange areas and flue gas pressure drop caused by lower temperature differentials. Therefore, the techno-economic performance of the flue gas heat recovery in power plant may not always increase with the increment of the recovered heat but have an optimum point.

14/03023 The GRAUTHERMIC-Tyres process for the recycling of granulated scrap tyres

López, F. A. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 103, 207–215.

The influence of thermolysis temperature (range 500–700 °C) on the products produced from granulated scrap tyres (GST) (diameter 2–6 mm) in a semi-batch pilot plant that uses several fixed bed reactors in parallel (GRAUTHERMIC-Tyres® process) was examined. This pilot unit consisted of six vertical fixed bed reactors in parallel, each with a capacity of 12 kg GST. Thermolysis proceeded in a normal air atmosphere. The solid (char), liquid (tyre-derived oil, TDO) and gaseous products generated at each temperature were characterized. The incondensable gas fraction was used to produce electricity via a gas turbine. The yields of the gas, TDO and char fractions were 15–22, 34–46 and 39–44 wt%, respectively, values that represent major recoveries from the GST feedstock. The TDOs were mainly a mixture of aliphatic and aromatic hydrocarbons and had very high GCVs (41–43 MJ/kg), higher than those of conventional liquid fuels. A large increase was seen in the polycyclic aromatic hydrocarbon content above 550 °C. The non-condensable gases obtained had a high GCV value (64–83 MJ/Nm^3), and produced 4.1–6.5 kWh electricity/g of GST in a gas turbine. The chars had a GCV of 27–28 MJ/kg, high ash (17–21 wt%) and zinc contents, and an essentially macroporous texture with a low BET surface area (46–78 m^2/g). The thermolysis of GSTs with cogeneration of gases by the GRAUTHERMIC-Tyres method would appear to be a viable means of valorizing GST.

14/03024 Thermal delay provided by floors containing layers that incorporate expanded cork granule waste

Tadeu, A. *et al. Energy and Buildings*, 2014, 68, 611–619.

This paper reports the computation of the thermal delay provided by concrete floors built with layers of cork and lightweight screed that incorporate expanded cork granule waste. The heat transfer by conduction across these multilayer systems is simulated analytically under unsteady boundary conditions. The thermal delay is computed for multilayer concrete floors with varying numbers of layers and layer thicknesses. The mass density and thermal conductivity of the various materials were determined experimentally. Given its heterogeneity, the specific heat of the lightweight screed was obtained indirectly using both the experimental results and the analytical model. The results obtained show the potential of these composites in applications for increasing the thermal performance of concrete floors, in particular the thermal delay and thermal resistance. The results show that the contribution of the insulating lightweight screed material's properties to thermal delay is more relevant in systems composed of few layers. The constructive solutions composed of a greater number of layers present higher thermal delay value.

14/03025 Utilization of waste glass powder for latent heat storage application in buildings

Memon, S. A. *et al. Energy and Buildings*, 2013, 66, 405–414.

The feasibility of using soda–lime waste glass powder for latent heat storage application was investigated. n-Octadecane was loaded into glass powder. The surface morphology, chemical compatibility, phase change behaviour, thermal stability and reliability were determined using scanning electron microscope, Fourier transformation infrared (FT-IR) spectrum analysis, differential scanning calorimetry, thermogravimetric analysis (TGA) and thermal cycling test. The thermal performance of cement paste composite phase change material (PCM) was also evaluated. The maximum mass percentage of n-octadecane retained by the glass powder was found to be 8. FT-IR results showed that the interaction between the components of composite PCM is physical in nature. The melting and freezing temperatures of the composite PCM were found to be 26.93 and 25.03 °C while the latent heat of melting and freezing were 18.97 and 18.95 J/g. TGA and thermal cycling results confirmed that the composite PCM is thermally stable and reliable. A thermal performance test showed that the cement paste panel with composite PCM reduced the indoor temperature by 3 °C. It can be concluded that the composite PCM can be used for thermal energy storage applications in buildings. Its usage will provide sustainable solution to reuse the waste glass. Thus, landfills can be saved for useful applications.